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Lean Performance Measures in a Supply Chain

Identifying Lean supply chain measures: a case study in the WPC industry

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ABSTRACT

In the existing global economic context it is crucial that companies understand the importance of the supply chain, so that they can maintain their respective competitive advantage. Several of the supply chain's approaches consider the customer and the definition of value as key features.

One easily associates the Lean philosophy to supply chains, with its basis of continuous improvement and elimination of waste. Companies which employ this philosophy begin with lean thinking, which highlights the customer and the definition of value. Therefore it is vital that companies identify what constitutes added value to the customer.

Thus we arrive at the reasons which have led to the creation of this dissertation. The motivation concerns the small amount of data found upon reviewing the existing literature of the application of Lean philosophy to the Wood-Plastic Composite Industry (WPC). Consequently the study's main goal is the identification of Lean performance measures.

This dissertation contains concepts of Lean philosophy and strategy to provide background for its practical part, after which, we explain the applied methodology: identification of the performance measures, application of strategy analysis tools, the development of a survey and its statistical treatment and finally interviews to management.

The results of the surveys have provided results which have helped identify the most important categories: time and flexibility; and the most relevant performance measures. The interviews' results provided input on management's knowledge and expectations of Lean, and the discovery of possible areas for improvement.

The major conclusion of this study is the importance given to Lean performance measures in the WPC industry's context, which can help in the implementation of Lean.

Keywords: Lean philosophy, lean performance measures, lean manufacturing, wood plastic composite industry.

RESUMO

No contexto económico global existente é de grande importância que as empresas percebam a importância da cadeia de abastecimento, para que estas mantenham a sua vantagem competitiva. Várias metodologias para cadeias de abastecimento consideram o cliente e a definição de valor como aspetos fundamentais.

É fácil associar a filosofia Lean a cadeias de abastecimento, com base na melhoria contínua e eliminação de desperdício. As empresas que utilizam esta filosofia começam pelo pensamento *lean*, que destaca o cliente e a definição de valor. Logo é importante que as empresas identifiquem o que constitui valor para o cliente.

Assim chegamos às razões que levaram à escrita desta dissertação. A motivação prende-se com a quantidade reduzida de dados encontrados aquando a revisão da literatura existente da aplicação da filosofia Lean na indústria de materiais em compósito madeira-termoplástico (WPC). Consequentemente, o objetivo principal do estudo é a identificação de indicadores Lean.

Esta dissertação contém conceitos da filosofia lean e de estratégia para facultar o conhecimento para a parte prática. Abordamos de seguida a metodologia aplicada: identificação dos indicadores, aplicação das ferramentas de análise estratégica, elaboração do instrumento de medição e o seu tratamento estatístico e finalmente entrevistas com a gestão de topo.

Os resultados dos questionários ajudaram a identificar as categorias mais importantes, no caso o tempo e flexibilidade e os indicadores mais relevantes. Os resultados das entrevistas, por seu turno, fornecem o *input* do conhecimento e expectativas do Lean que a gestão de topo tem, e a descoberta de áreas com oportunidades de melhoria.

A principal conclusão deste estudo é a importância atribuída aos indicadores lean no contexto da indústria de materiais em compósito madeira-termoplástico, que pode ajudar na implementação do lean.

Palavras-chave: Filosofia lean, indicadores lean, manufactura lean, Indústria de materiais em compósito madeira-termoplástico.

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ABBREVIATIONS

BSc – Balanced Scorecard

BU – Business Unit

GDP - Gross Domestic Product

JIT – Just-in-Time

SC – Supply Chain

SCM – Supply Chain Management

WPC – Wood-Plastic composite

1. INTRODUCTION

1.1. Framework and Motivation

In the global economic context it is of the utmost importance that companies understand the influence of the supply chain and its continuous improvement, for maintaining their competitive advantage. There exist several approaches for supply chain philosophies and all these share some features, but it is vital that they recognize the customer and the definition of value in the supply chain.

One easily associates Lean philosophy to supply chains, with its basis of continuous improvement and elimination of waste, this is a popular approach. Companies who employ this philosophy begin with lean thinking, which has great emphasis on the customer, the definition of value and the creation of value. Thus the lean thinking process is essential for companies and is very important in the existing economic situation due to its ability to optimize a company's processes.

As such, it is important that companies identify what constitutes value to the customer, so that they may create the necessary processes to accomplish added-value and thus even surpass the customer's expectations. The identification of value is crucial for companies to achieve success. Because if this is not done than lean's objectives of waste removal and continuous improvement cannot be accomplished.

Considering the application of lean to a supply chain, it is fundamental that companies correctly assess and/or evaluate their performance. In order to accurately measure performance it is very useful to establish a set of measures, designated as performance measures. When these are applied to the lean philosophy, it is fundamental to identify the correct lean performance measures for each situation. As lean contemplates several aspects, it is essential to specify performance measures.

It is crucial that companies improve themselves in order to gain competitive advantage over rivals and present the most attractive offers of services or products to their existing and potential clients, in the existing economic climate. Thus, every company should have the ability to understand its competition and the competitive forces that affect its success. A few key points that should be considered when performing these analyses are: flexibility of resources, product differentiation and choosing the best suppliers; for these can be vital strategies in the pursuit of gaining competitiveness in competitive markets. As such, companies have to assure their customers that their order gets delivered when they want it, how they want it and where they want it. This has to be done while maintaining profit and considering resource planning; but always bearing in mind the customer's satisfaction and goodwill.

This dissertation is an attempt at examining how the Lean philosophy can be applied in the Wood-plastic composite (WPC) industry. After reviewing the literature we have found that there is a small amount of data regarding the application of lean in the Wood plastic composite industry and so we have tried to further develop this study.

In order to discover if there are possibilities for improvement, a case study of a company (Tecnodeck) that operates in the WPC industry has been done. Its results are discussed in order to create new strategies, together with the applied performance analysis tools.

1.2. Objectives

After presenting our motivation to write this dissertation, we have to choose which direction to take, which can be accomplished by setting the objectives. The goal of this dissertation is the identification of lean performance measures in a supply chain and based on the literature revision, potential performance measures will be identified.

Considering the dissertation's goal we can present the main question that the dissertation will try to answer. "How does the wood-plastic composite industry value the identified lean performance measures?" We will try to explain this through the case study's company evaluation of the identified performance measures.

Several strategic analysis tools will also be employed in order to give a clearer picture of the company's strengths and weaknesses, and to provide a basis for the creation of future strategies. The analysis tools that will be employed are: SWOT analysis, PEST analysis, BCG Matrix, Porter's Five Forces and Balanced Scorecard.

A survey will be created to measure the users input regarding the identified performance measures. With these results, strategies can be devised to explore opportunities and gain competitiveness. Employee suggestions, which can help discover underrated or overrated performance measures, will also be taken into account.

1.3. Dissertation structure

In order to provide a framework for the motivation and objectives of this dissertation, it is important to correctly structure it. This dissertation has been structured in the following manner:

- Chapter 1 contains the introduction and objectives, where the motivation and scientific interest of this dissertation are presented.

- Chapter 2 refers to the literature review: strategy concepts and strategy related tools are presented first, secondly Lean philosophy is introduced, its history, advantages and disadvantages. Thirdly, a brief definition of supply chain is given which will help to present the lean supply chain paradigm. Finally lean performance measures are presented.

- Chapter 3 explains the methodology used in this work. Theoretical concepts and methods concerning the case study are explored in the scope of this situation. Surveys were created and delivered to the company in order to gain knowledge of the importance employees give to the lean performance measures.

- Chapter 4 is dedicated to the Discussion of the case study. Firstly we explore the five strategic analysis tools; secondly we comment upon the survey's results and their statistical treatment; thirdly we have the results of the interviews with management and finally we create the strategies for each of the three countries based upon Porter's generic strategies, results from the survey and interviews with management.

- Chapter 5 relates to the conclusions based upon the results of the performance analysis tools, surveys and interviews.

- Chapter 6 contains the bibliography.

2. LITERATURE REVIEW

2.1. Introduction

In this chapter we shall introduce the major theoretical concepts that will help provide a background to the required knowledge of the practical part of this dissertation. Firstly, we present concepts containing several strategic analysis tools: SWOT, PEST, BCG, Porter's Five Forces and Porter's generic strategies and the Balanced Scorecard. Secondly we present concepts related to lean philosophy and its features. Thirdly, we present concepts related to the supply chain and the lean & supply chain paradigm. Finally we present concepts related to lean performance measures and clarify this definition. Because when performing the literature revision, we found different terms that relate to the same concept.

These concepts will be aided by figures or tables when necessary, in order to facilitate user comprehension. This chapter can serve as a knowledge platform for the practical part.
We will begin by discussing strategic planning, which is a foundation in the process of developing a strategy.

2.2. Strategic Planning

It is vital for a company to attain success and success can be achieved if the company has an edge over its rivals, be it in product or service; for this allows a company to stay in business and thrive. This edge has to be taken into consideration when developing a strategy; the strategy must make full use of the advantage the company possesses. With a strategy in place, a company will have an advantage over its rivals and thus ensure that it continues to operate.

The result of using a company's advantage in the creation of a strategy is entitled by some as competitive advantage. Competitive advantage happens when a company achieves one of two possible advantages: cost advantage or differentiation advantage; this allows a company to have a competitive advantage over its rivals. The first advantage occurs when the company delivers the same product/benefits as its rivals but at a lower cost. And the second advantage occurs when a company delivers product/benefits that surpass that of its rivals. By having competitive advantage, a company is able to create superior value for its clients and thus potentially earn bigger profits. These are considered positional advantages, as they describe a company's position in its industry as a leader, in one of the two advantages.

After regarding competitive strategy and its significance to every company, it is important to explain what tools may help formulate strategies. Strategic analysis tools help companies get a clearer picture of where they are and where they should be going to. They should first assess the company's environment and only after this can the strategic tools correctly evaluate a company's strategy. Although there are several strategic tools we could apply, such as: Critical success factors, Porter's diamond, Treacy and Wiersema's value disciplines and/or the GE/ McKinsey matrix; we have decided to apply the following tools: four strategic tools regarding the industry's environment (SWOT, PEST, BCG Matrix and Porter's Five Forces) and one strategic tool regarding the company's strategy (Balanced Scorecard).

2.2.1. SWOT Analysis

The first strategic tool analyzed is the SWOT (**S**trengths, **W**eaknesses, **O**pportunities, **T**hreats) analysis since it evaluates the environment where a company operates. It is essential that companies discover about their environment in order to achieve success. We will analyze strategic tools related to the company's environment first and only after this can we successfully analyze the company's strategy.

SWOT analysis is one of the most popular strategic tools due to its factors analysis of strengths, weaknesses, opportunities and threats of the environment.

Strengths and weaknesses belong to the internal feature of the environment and show the existing situation of the company. While opportunities and threats belong to the external feature of the environment and show if there are changes in the environment that can affect the company.

The four factors are now described in greater detail:

- Strengths – factors that allow the accomplishment of a company's objectives. Strengths are very important to achieve and maintain success, and thus should be maximized;
- Weaknesses – factors that stop a company from accomplishing its objectives. Weaknesses decrease the probabilities of a company's success and growth, and so they should be minimized and eliminated. A plan to fight weaknesses is vital for the company's success;
- Opportunities – factors that a company can benefit from. Companies can gain competitive advantage through opportunities as long as they can capitalize when these present themselves;
- Threats – factor that jeopardize the company's profit. Threats can be related to weaknesses and are not controllable.

SWOT is thus an important tool when analyzing a company's strategic positioning and its environment and it allows a company to find out:

- What it does better than its rivals;
- What rivals do better;
- If it is making the most of available opportunities;
- How to react to changes in the environment.

Figure 2.1 – SWOT analysis

The combination of the four factors showed in Figure 2.1 help devise strategies for a company, as depicted in Figure 2.2.

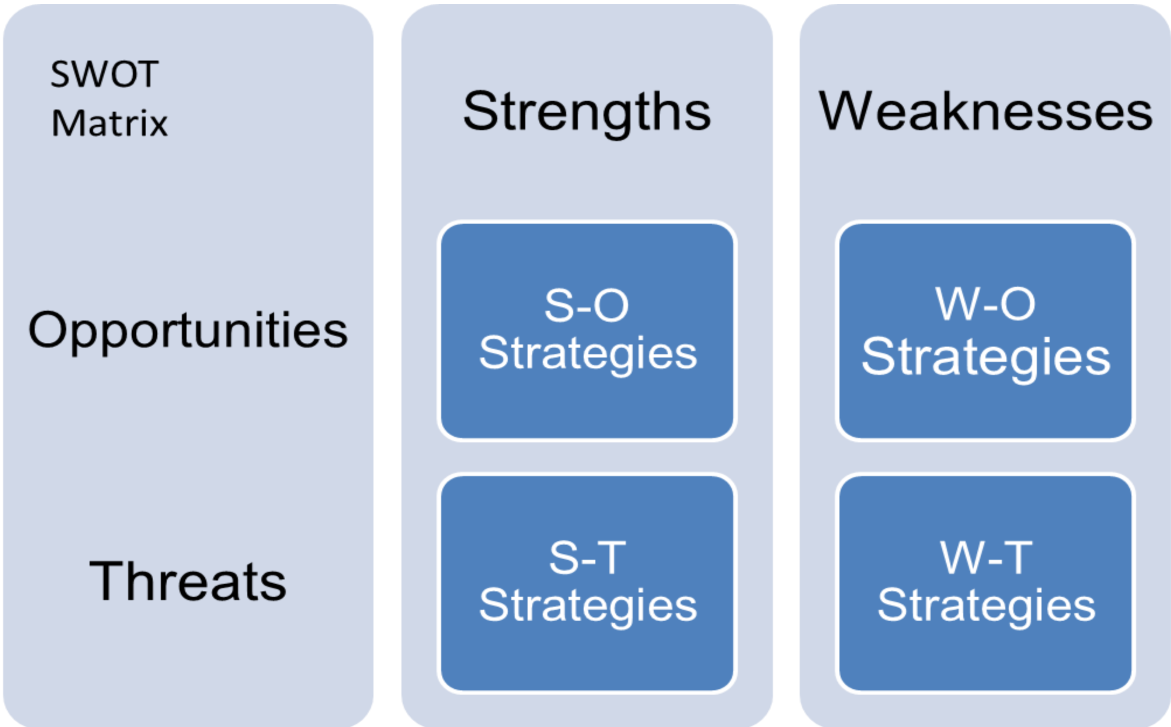

Figure 2.2 – SWOT/TOWS Matrix

A company should always be encouraged to try to create a strategy by mixing strengths and opportunities in order to develop competitive advantage, and therefore a company may not constantly adopt the most profitable strategy. The strategies with the mixed factors are shown in Figure 2.2 above and are further described below:

- S-O strategies, search for opportunities that are a good match to the company's strengths;
- W-O strategies, try to overcome weaknesses to search for opportunities;
- S-T strategies, try to identify a way that the company's strengths can reduce vulnerability to threats;
- W-T strategies, try to develop a preventive action for weaknesses, so that these don't increase the risk of threats.

2.2.2. PEST Analysis

After discussing the SWOT analysis and its evaluation of the company's environment, it is useful to apply another analysis to the environment to cover eventual gaps.

PEST (**P**olitical, **E**conomic, **S**ocial, **T**echnological) analysis is a tool that can be used by companies to get a clearer picture of the environment they work in. It does this by analysing four factors: Political, Economic, Social and Technological (PEST).

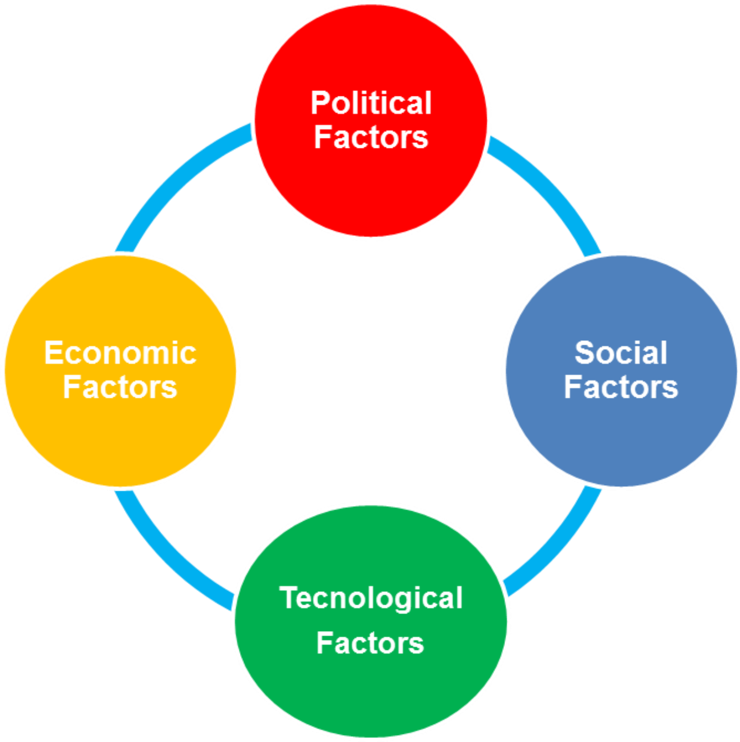

Figure 2.3 – Pest Analysis

Each of the four factors is now described:

- Political factors contain official regulations and legal issues that define the rules under which the company works;
- Economic factors show how buying power of clients is affected and how a company operates and makes decisions;
- Social factors show how client's requirements are affected and the size of potential markets. They contain demographic and cultural aspects of the external environment that can reveal trends;
- Technological factors show how to lower barriers to entry and influence outsourcing decisions.

The PEST analysis tool should thus be performed for each country the company operates in or has an interest.

2.2.3. BCG Matrix

The BCG matrix is another strategic tool that allows a company to evaluate the market it operates in. It is a tool used to discuss resource distribution between strategic business units. It considers that a company's business units can be divided and classified into four categories based on the combination of market growth and market share; the BCG matrix considers that market growth is related to industry attractiveness and market share is related to competitive advantage (Mercer, 1993 *apud* Jayantha & De Silva, 2011).

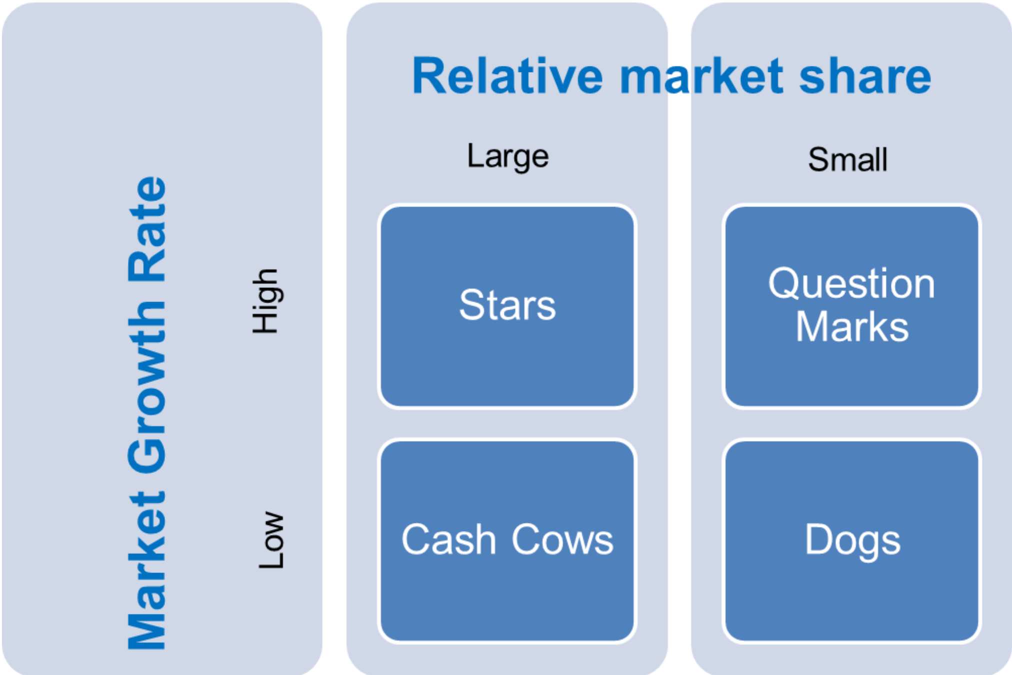

Figure 2.4 – BCG Matrix

Figure 2.4 considers that an increase in market share results in an increase in generating money and that a growing market needs investment to increase capacity and requires money to do so. We will now define each of the four situations shown in Figure 2.4 above:

- Cash Cow – is a business unit (BU) that has a large market share and low growth rate. This BU requires little investment and generates capital that can be invested in other BU's. A cash cow can provide the capital to change Question Marks into Stars;
- Dog – is a business unit (BU) that has a small market share and low growth rate. Although this BU doesn't need much capital, it uses capital that can be better invested elsewhere. If a Dog doesn't have a strategic objective, then it should be divested if there is a small probability of gaining market share;
- Question Mark – is a business unit (BU) that has a small market share and high-growth rate. Question Marks require large resources to gain market share. It is unknown if a Question Mark will achieve success and become a Star or fail and become a Dog because of its large expenses;
- Star – is a business unit (BU) that has a high-growth rate and large market share. Stars may generate capital but also require capital to reinvest in order to maintain their leadership. A Star may become a Cash Cow if it achieves success once the industry matures. Companies should always have Stars that can eventually become Cash Cows in order to secure capital for the future.

2.2.4. Porter's Five Forces

We now come upon the fourth analysis related to the company's environment and market, which hopefully complements the previous three.

Porter's five forces is a tool that analyses five different forces that influence an industry. This tool allows managers to understand the industry where their company operates and thus it can provide an advantage over rivals.

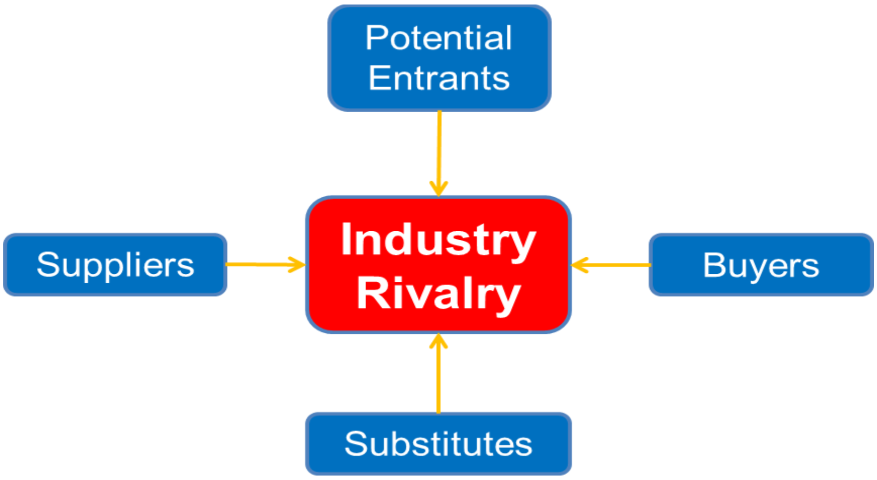

Figure 2.5 - Porter's Five Forces Model

Rivalry

Rivalry is a result of companies that operate in the same industry, because companies will always do their best to gain competitive advantage over one another. In order to gain competitive advantage a company can do the following: change processes, improve product differentiation, use different means of distribution and/or explore supplier relationships. Thus one can say that companies can be in two general situations regarding the industry they operate in. Industries can have multiple companies with small market shares or they can have few companies with larger market shares. Therefore, although it is important that a company gains an advantage over its rivals, it still has to contend with the intensity of rivalry.

Substitutes (Threat of Substitutes)

The threat of substitutes relates to products with the same purpose, but which belong to different industries. A substitute product can affect price and demand; as demand varies due to more products being available, a close substitute product can affect price by making it more difficult to raise prices.

Buyers (Buyer Power)

It is the power that clients can have over the industry. If it is high, then the client has a strong bargaining power and can argue prices. This is an unusual situation.

Suppliers (Supplier Power)

It is the power a supplier can have over clients or a manufacturing industry. If it is strong then suppliers can raise prices and increase profits more easily.

Potential Entrants (Threat of Mobility)

Competition increases when new companies enter the industry; they often face some obstacles upon entering, designated as barriers to entry. Barriers to entry, which are a useful tool when considering increasing a company's competitive advantage, can decrease the number of new companies and thus keep the profit level for existing companies. There are also barriers to exit, which are similar to barriers of entry because they make it difficult for a company to leave the market and so it must stay and compete.

Porter's five forces is a good tool to analyze a company's competing environment.

2.2.5. Porter's Generic Strategies

It is important to know how to create a strategy for a company. For this it is useful to consider basic strategies such as Porter's generic strategies for example, which can be used to help bridge the environment analysis tools (SWOT, PEST, BCG, Porter's five forces) and the strategy assessment analysis tools such as the Balanced Scorecard. There are also other basic strategies which we can consider, such as Treacy and Wiersema's strategies (Product Leadership, Operation Excellence and Customer Intimacy) that are more focused on the customer, by having a customer relationship factor. But considering that Porter's generic strategies are more market-oriented we have chosen these as the basis to develop our strategies in the practical part of the dissertation (Treacy, 1995).

Therefore Porter's generic strategies will be defined and discussed in this sub-chapter.

Porter argues that a company's strengths can be: cost advantage or differentiation. These strengths can be applied in a broad or narrow scope, which generates three generic strategies: cost leadership, differentiation and focus. These strategies aren't dependent on the company or the industry. The three strategies are presented below in Table 2.1 (Porter, 1999).

Table 2.1 – Porter's Generic Strategies
(Porter, 1999)

Target Scope	**Advantage**	
	Low Cost	**Product Distinctiveness**
Broad (industry wide)	Cost leadership	Differentiation
Narrow (market segment)	Focus (low cost)	Focus (differentiation)

Cost leadership strategy

The first strategy is the cost leadership strategy and it can be applied to a company that is a low cost manufacturer. The company can sell products at prices below the average industry prices in order to increase market share or the company can sell products at the industry's prices that will result in higher profits than its rivals.

Companies may reach these cost advantages by: improving process efficiency, having single access to lower cost raw materials and/or optimizing their outsourcing.

This strategy has risks and one of them is when other companies surpass the company in the technology aspect, therefore eliminating the company's competitive advantage (Porter, 1999).

Differentiation strategy

The second strategy is differentiation and it requires the development of a product or service that offers the clients distinctive or unique attributes, which are valued by clients. Clients recognize these attributes as being better or different from what rival companies offer. This unique attribute may let the company charge a higher price for its product or service. Consequently, this can help save extra costs that the attribute may incur in the product or service's price.

This strategy contains certain risks, such as: rivals copying the company's products and change in customer trends (Porter, 1999).

Focus strategy

The third strategy is the focus strategy. This strategy aims to narrow segments of the market, where it tries to achieve a cost advantage strategy or differentiation strategy. The focus strategy is based upon the principle that the needs of the group are better served if a company is only focused on one segment. Companies that adopt this strategy usually have a loyal customer base, which hinders potential rivals. Although because of the narrow focus, companies that adopt this strategy will have less bargaining power with suppliers.

This strategy also has it risks, some of which are: imitation and variations in target segments (Porter, 1999).

After defining each of the three strategies, it is important to discuss their implementation. Porter argues that a company should employ only one strategy because if a company mixes strategies, it can run the risk of losing its strength and its competitive advantage. Only if a company can separate its business units, can it apply different strategies to each one without losing its strengths (Porter, 1999).

2.2.6. Balanced Scorecard (BSc)

Only after successfully explaining the previous strategic analysis tools related to the company's environment and Porter's generic strategies that help bridge the two different types of analysis, can we discuss the Balanced Scorecard tool. The purpose of the BSc is to evaluate the company's strategy because only after examining the environment and creating a basis for the company's strategy can we effectively concentrate on analyzing and shaping the company's strategy.

> "The balanced scorecard is a strategic performance management system that links performance to strategy using a multi-dimensional set of financial and non-financial performance measures. It focuses on better understanding the causal relationships and links within organizations and the levers that can be pulled to improve corporate governance." (Dye, 2003 *apud* Punniyamoorthy & Murali, 2008)

The BSc tool was created by Kaplan & Norton (1996, pp.30-31) and is used by managers to analyze a company's performance. It is a tool based upon a group of performance measures divided into four perspectives: financial, customer, internal processes and learning and growth. According to these authors the Balanced Scorecard expresses the vision and strategy of a business unit into objectives and measures in four separate perspectives:

- The 1st perspective - Financial - shows the company as it wants to be regarded by its shareholders;
- The 2nd perspective - Customer - shows how the company wants to be regarded by its customers;
- The 3rd perspective - Internal Business processes - describes the processes which the company must excel at to satisfy its customers and shareholders;
- The 4th perspective - Learning and Growth - contains the changes and improvements which the company needs to perform in order to realize its vision.

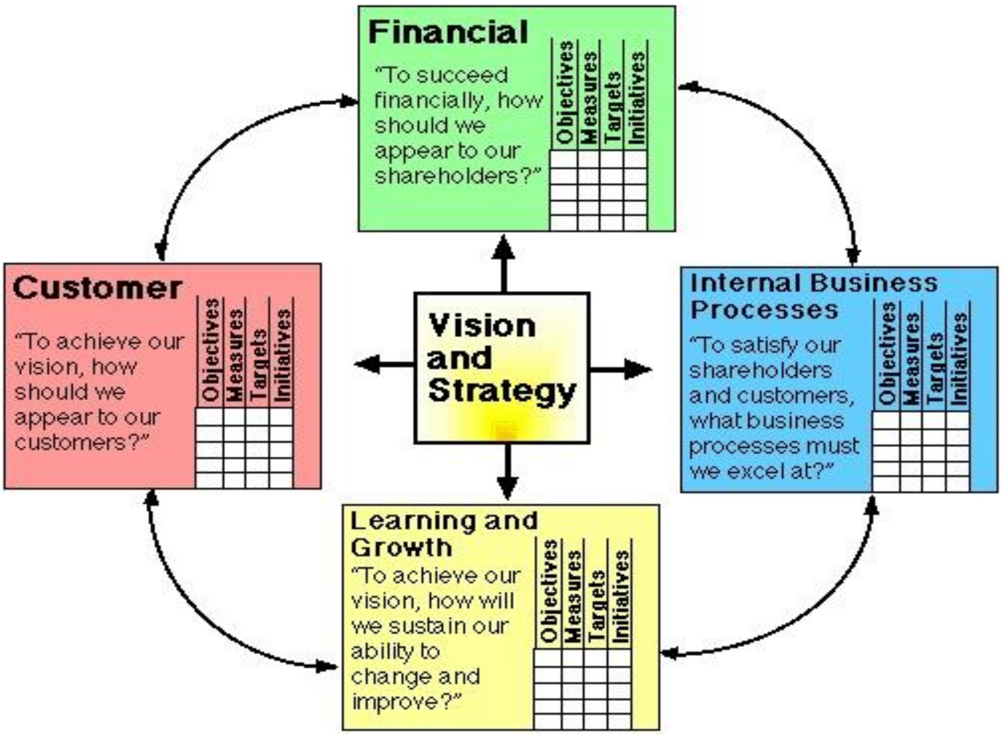

Figure 2.6 – Balanced Scorecard
Available at: (http://www.valuebasedmanagement.net/images/figure_bsc.jpg)

The BSc can be used to (*Idem. Ibidem*):

- Explain and gain consensus about strategy;
- Find and align goals to strategy (Norreklit, 2000);
- Link strategic objectives to long-term targets and annual budgets;
- Obtain feedback to improve strategy;
- Communicate the strategy to the whole organization.

The Balanced Scorecard has the great benefit that its perspectives share connections; as a result there are causal relationships between its perspectives. This is exemplified in Figure 2.7 below.

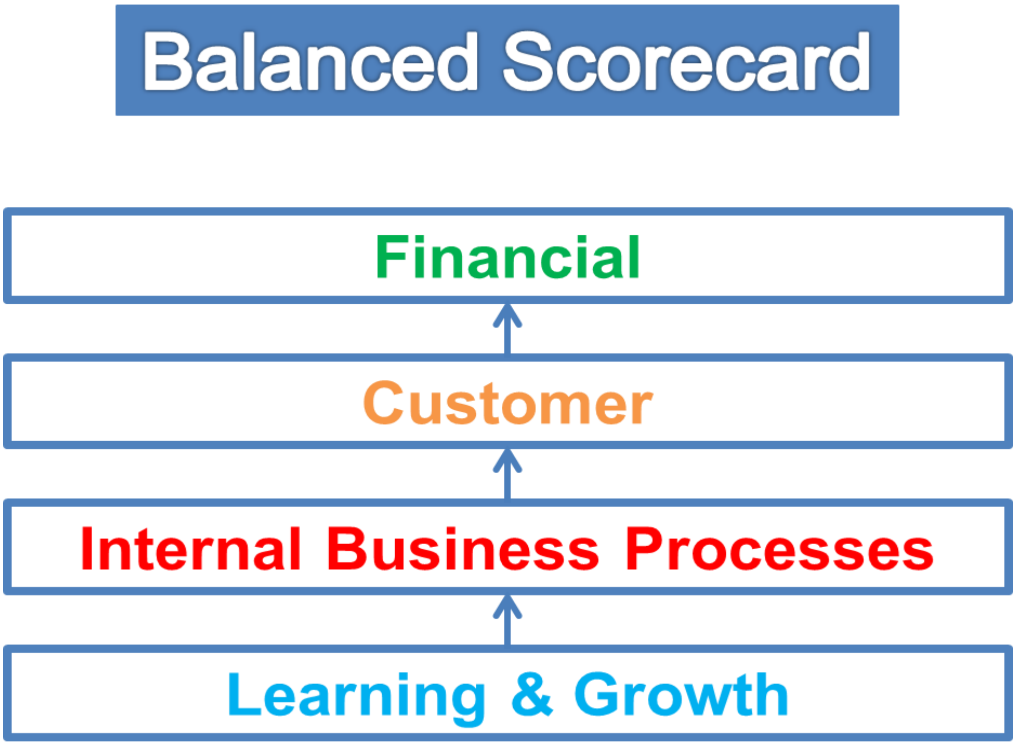

Figure 2.7 – BSc measures' drivers

Observing Figure 2.7 it is fundamental to properly define causal relationships between measures of the four perspectives when creating a BSc. It is important to know that financial measures can report about past performance and non-financial measures can be the drivers of future performance and value creation (Kaplan & Norton, 1996, pp.8).

2.3. Lean Philosophy

After discussing strategic planning and strategic analysis tools related to the company's environment and strategy, we will now start to discuss the Lean philosophy. Since it is the study's objective to identify lean performance measures in the wood-plastic composite industry and the importance the industry gives to these performance measures (sub-chapters 4.3 and 4.4).

In a broader perspective, the lean philosophy relates to strategic planning in respect that lean itself is a strategy. Companies can apply lean in order to obtain better performance results and to eliminate any possible actions, plans or activities that contribute to the decrease of the company's performance results.

On a more specific level, one of lean's components, Value, is also one of strategic planning's basis for competitive advantage. One of Competitive advantage's strategies states that by having a superior product/service than its rivals, companies can surpass their rivals. This can be done through the identification of what customers' value, which the lean philosophy does when it is trying to create value. Therefore by correctly identifying what customers consider as value,

lean is able to eliminate waste in actions, plans or activities. As eliminating waste is lean philosophy's main objective (see definition below).
Because of the two explanations we have provided, we have chosen to integrate lean philosophy in the strategic planning chapter as lean will be applied to the wood-plastic composite industry. We will try to define the lean philosophy, its major components and enumerate lean's advantages, disadvantages and tools/practices/techniques.

> "Leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule." (Naim & Gosling, 2011)

Lean's goal is to add value to the product/service by eliminating waste. Waste is eliminated by targeting activities that do not add value. These activities can use/spend resources unnecessarily and will thus increase the product's price. Therefore it is very important to correctly identify all activities. While identifying activities it is important to stress out that although an activity may not be adding value to the product/service, it can be important to the manufacturing process and so it is wrong to eliminate it.

(Dües et al., 2013) enumerates a list of Lean attributes. These are presented in Table 2.2.

Table 2.2 – Lean attributes
Source: (Dües et al., 2013)

Attribute	Lean Paradigm
General Purpose	Maximize profits by reducing costs
Focus	Focus on cost reduction and increased flexibility through continuous elimination of waste and non-value adding activities across the Supply Chain
Customers	Economic customer driven by costs
Customer Satisfaction	Satisfying customers by reducing costs and lead times
Organizational Structure	Static organizational structure with few levels of hierarchy allowing empowerment of employees
Supply Chain	
Lead Time	Reducing lead times if it doesn't increase cost
Relationship with Suppliers and Customers	Close, collaborative, reciprocal, long-term relationships with few selected suppliers; Demand information is shared across the supply chain; Create a network of suppliers to build common understanding and learning about waste reduction and operational efficiency in the delivery of existing products and services.
Product Design	Maximize performance and minimize cost
Raw Material Sourcing	Supplier attributes comprise low cost and high quality

Manufacturing	Maintain high average usage rate; Use JIT practices, “pulling” products based on demand.
Inventory	Generates high turnover and minimizes inventory throughout the supply chain to decrease costs and free up assets
Transport	Minimizing material handling during manufacturing encourages frequent small deliveries of supplies and finished products
End-of-life	Consideration ends with sale of product; No concern for impact of product usage or end-of-life recovery.
Business Results	
Business Results	Quality, cost, delivery, customer satisfaction and profitability
KPI (key performance indicators)	Cost and service level
Dominant Costs	Physical costs
Tools	
Principal Tools	Value Stream Mapping(VSM)
Waste Reduction Techniques	Seven wastes: overproduction, waiting, transportation, inappropriate processing, defective parts and rejects, unnecessary inventory and unnecessary motion.
Tools/Practices	Value Stream Mapping, inventory minimization, higher resources usage rate, dissemination of information across the supply chain, JIT, 5S, shorter lead times.

A few attributes from Table 2.2 that we considered important for this dissertation regarding customers, inventory and lead times, are explained below:

- The Lean customer is driven and satisfied with cost and lead time reduction;
- Keeping excessive inventory represents extra cost and thus a risk to the company;
- Decreasing transportation lead times to create supply chains that are more responsive and decreasing the overall need for transportation.

Lean provides several benefits to the companies where it is implemented such as: decrease of clients’ lead-times, increase of supply chain speed, decrease of waste, improvement of product quality, Just-in-time delivery, reduced inventories, increase of labor productivity, decrease of space usage and decrease in manufacturing costs.

Although Lean has several benefits, one gap has been pointed out. It concerns variability in the supply chain, as orders can change without notice there is the possibility that supplier fails to deliver the correct quantity at the right time or place with perfect quality. Lean has a lack of adequate responses to cope with this kind of problem (Womack et al., 1990 *apud* Shah & Ward, 2007).

Upon reviewing the Lean philosophy, it is important to discuss in greater detail Lean's aspects: Lean Thinking, Waste, Creation of Value, Flow and Lean tools/ techniques. In order to understand the scope of the lean philosophy.

2.3.1. Lean Thinking

> "The dynamic, knowledge-driven, and customer-focused process through which all people in a defined enterprise continuously eliminate waste with the goal of creating value." (Sun, 2011)

It is important to understand how the process of applying Lean to a product or service starts, this process begins with lean thinking.

The concept of lean thinking starts with the client and the definition of value. When a manufacturing process is able to deliver value to the client, then that is where Lean Thinking may begin being applied. Lean Thinking can be applied to process industries (industries where the main production processes happen continuously or occur on a batch of materials that is indistinguishable) and to the specific manufacturing processes belonging to these industries.

In order for a company to be truly Lean it needs to guarantee the flow of value across its supply chain and this begins with waste elimination. Waste can be reduced or eliminated from various manufacturing processes, which have been previously identified as non-value adding activities.

If it is the company's objective to implement Lean, then this process can be easier when considering a method developed by Melton (2005):

- Record existing process performance – how it is done;
- Define value and remove waste;
- Detect unwanted effects and identify their root cause in order to determine the real problem;
- Fix problems and redesign their processes;
- Test and prove that value is being delivered to the customer.

After a company has implemented Lean, it can continue to improve if it applies Lean thinking in the company. Melton also has a few guidelines that will help a company apply Lean thinking:

- Review the value chain for certain customers;
- Review processes (business and manufacturing) with the help of cross-functional teams, which have the power to change processes;
- Always search for waste, checking regularly that value is delivered to customers and controlling the flow.

Lean thinking is vital after companies have taken the first step to implement Lean philosophy and try to improve their processes. It is important to consider the resistance to change of workers. Because Lean thinking seeks to know how things are done and why, this usually bothers workers and goes against lethargy found in most companies. But the increase in efficiency and profits are proof to convince workers sceptical about Lean (Melton, 2005).

After discussing the process of lean thinking we shall now discuss one of lean thinking's applications, waste removal and more importantly what is waste.

2.3.2. Waste

> "Any activity in a process which does not add value to the customer is called 'waste'. Sometimes the waste is a necessary part of the process and adds value to the company and this cannot be eliminated, e.g., financial controls." (Melton, 2005)

Waste removal is an essential component of the Lean philosophy and so it is very important correctly identifying what constitutes as waste. After which, waste removal processes can be applied.

Melton mentions that it is vital that waste be eliminated, but to discover how it is done is also very important, because waste can be eliminated and happen again if its origin is not eliminated. But one has to take into consideration that sometimes waste is a necessary part of the process and so it cannot be eliminated, which has been stated previously.

At an early stage the identification of waste in processes is easy and has the possibility of large savings. But as processes improve, waste reduction becomes incremental. Therefore it is very important to always question what to do because that is a good first step to stop creating waste.

There are several techniques and tools one can use to identify and classify waste, such as the three MU's and the seven causes of waste.

The three MU's approach to identifying waste is based upon matching the manufacturing capacity to production (Amaro & Pinto, 2007):

- *Muda* (waste) – capacity exceeds production;
- *Mura* (inconsistency or variation) – if capacity is smaller or larger than production;

- *Muri* (irrationality) – production larger than capacity.

The second method, known as seven causes of waste consists of (Melton, 2005):

Figure 2.8 – The seven types of waste
Source: (Melton, 2005)

In order to eliminate waste, it is good to create a process diagram to understand the location of the inventory holding sites, and to improve or eliminate travelling routes.

The potential gain with the elimination of waste is significant. However it is necessary to be aware of activities which don't create value but are necessary; these should be minimized to decrease their influence. Finally it is important not to lose focus of the creation of value while eliminating waste (Amaro & Pinto, 2007).

After identifying what constitutes waste to a company, it is easier to identify which activities are adding value to the company's product. So we arrive upon value, its creation and identification processes that are crucial when understanding what features the customer desires and values most. We will try to explain this in the following sub-chapter.

2.3.3. Creation of Value

> "The creation of value is defined by any activity which converts the product or service into an added value to the client." (Amaro & Pinto, 2007)

As stated before a company needs a product/service that sets it apart from its industry rivals. By having a product/service that has attributes the customer values above other products/services, the company is able to attain competitive advantage. Creation of value is a crucial component of the lean philosophy.

The same authors state that value can be defined as a combination of processes and operations that must be done in the best possible way to deliver a product/service, with the best quality, at the lowest cost and at the right moment.
A company gains competitive advantage when it has one or more value creating activities, thereby offering the customer more value for its product/service than its rivals. Superior value can be created through lower cost or superior benefits of the product/service the client acquires. Because clients will choose a product/service with superior value ahead of others.

After explaining the definition of Value in the Supply Chain, it has to be stated that value is a critical component to Lean. In the Lean approach, value can be defined as ever-changing from customer to customer and therein lays the essence of value identification. As customer's requirements are always different and if one doesn't identify what the customer requires then Lean can't be properly applied. So, one of the first steps is to identify value and define value propositions for the customers (Melton, 2005).
Regarding Melton's identification of value, Ciarniene & Vienazindiene (2012) state that it is important to find the answer to the following questions:

1. What do customers desire?
2. When and how do they want it?
3. What mix of features, capabilities, availability and price will be favored by the customer?

When considering added-value, one is always reminded of how this value is transmitted along the supply chain. This happens through the flow of production and consequently the flow of value throughout the processes that make up the supply chain.

2.3.4. Flow

Flow is a difficult concept to understand. In a simple manner it can be said that Flow is the opposite of mass production systems. It is because of the lack of flow that large warehouses exist to store inventory, which results in unnecessary maintenance and space expenses.
To understand flow it is important to understand the notion of value stream. Value stream is the connection of activities that deliver value to the customer and bridge functional and organizational areas. In order for companies to be truly Lean, they have to guarantee the flow of value (Melton, 2005).

After discussing Lean's features, it is important to know how these can be applied in companies. For this we will present the tools, practices and techniques that Lean makes use of.

2.3.5. Lean tools/practices and techniques

There are several Lean tools, practices and techniques that a company may employ when applying Lean. Some of these techniques are listed below (Melton, 2005; Ray et al., 2006):

- *Kanban* – visual signal that aids production flow by pulling the product through the manufacturing process as the client's orders come in;
- 5 S's – visual housekeeping technique system which gives control back to the shop-floor (5 S's meaning: Sort, straighten/stabilize, shine/sweep/system cleaning, standardize and sustain);
- Visual control – method of measuring performance at shop floor level that is visual and owned by the operator team;
- Poke yoke – error proofing mechanism;
- SMED (single minute exchange of dies) – changeover reduction technique;
- Cellular manufacturing – makes the product batches as small as possible (Ray et al., 2006);
- Total Productive Maintenance (TPM) – comprises total effectiveness, total preventive maintenance and total participation;
- Value Stream mapping – process that tracks the product from its origin to the finish.

One of Lean's most important techniques is level scheduling also known as *Heijunka*. Level scheduling consists in eliminating waste through production planning, by analysing orders' historical data and their variability to ensure long term continuous flow.

Another important Lean technique is Just-in-Time production (JIT). JIT's main objective is to manufacture the required quantity at the moment the customer orders it. By doing this, JIT allows for: the reduction of costs, decrease of lead and setup times, reduction of queues and lot sizes.

After discussing Lean philosophy, we have to consider the supply chain every company has, because the supply chain plays a tremendous part when companies want to achieve success. If the supply chain's components are not working properly it will be very hard for the company to be successful. We will discuss the supply chain's importance and how it can be related to the Lean philosophy.

2.4. Supply-chain

> "A supply chain is defined as a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/ or information from a source to a customer." (Mentzer et al., 2001)

A supply chain is intrinsically linked to the company's strategy, if not then the company will probably fail. In order for the supply chain to successfully implement the company's strategy, companies can use the Balanced Scorecard strategic analysis tool. BSc's focuses on the company's strategy and two of its main uses are: to align strategic objectives to long-term targets and budgets and to communicate the company's strategy to its workers. If this is accomplished then it is a great step towards the company's success.

Every manufacturing company that has a supply chain must have one that runs smoothly, efficiently and quickly, so that it can manufacture incoming orders flawlessly.

Christopher regards the supply chain as a network of organizations, from supply to distribution, connected by different processes or activities that create value for the end-customer (Christopher, 1992 *apud* Mentzer et al., 2001).

During the 80's and 90's several companies discovered that it was necessary to improve their supply chain and not just the internal performance of the organization. Thus Supply Chain Management (SCM) became an important strategic component of competition in the existing economy (Behrouzi & Wong, 2011).

Kisperska-Moron & de Haan (2011) argue that supply chains compete in markets because of trends like decreasing a product's lifetime and product propagation in markets. All of the supply chain's elements must work towards the common goal of satisfying a customer's ever-changing demands. These demands can change according to the product's life cycle or customer's trends and so supply chains should adapt their strategies in order to keep their customers and gain new ones.

We have to consider the relationship between supply chain and Lean, as this interaction will provide a company with greater possibilities of achieving success through operational accomplishment.

2.5. Lean & Supply-Chain Paradigm

2.5.1. Definition and objectives

It is vital that lean philosophy and supply chain merge into a single entity without problems or delays. This would be an improvement. The supply chain will benefit from Lean's relentless methods that eliminate waste, create value and seek improvement opportunities.

Checking, measuring and improving performance is vital to the success of a Lean Supply Chain. As a result of applying Lean to a supply chain, there have been improvements in quality conformance, delivery speed, delivery reliability, and cost (Stratton & Warburton, 2003). Another pillar for the success of a lean supply chain is to find and understand what the customer values in a product/service, because customer's demands change constantly. Companies can rely on a few features that customers always value such as: delivery time, cost, quality or flexibility (Behrouzi & Wong, 2011). When faced with an economic crisis, clients and markets valued characteristics change; it is of the utmost importance that companies are aware of these changes.

Summarizing, the Lean supply chain paradigm is an approach based upon cost and time reduction, in order to improve effectiveness. The goal of the paradigm is to optimize all processes belonging to the supply chain, by identifying simplifications, decreasing waste and minimizing activities that do not create value (Duarte & Machado, 2010).

2.5.2. Features

After defining the paradigm and discovering its objectives, it is important to know how Lean differs from the usual supply chain strategies. We list a few differences of Lean supply chain's features (Pinto, 2010):

- Quick to respond to market variability and customer's demands;
- Emphasis on synchronizing collaboration across the supply chain;
- Quick to adapt to new challenges and opportunities provided by unpredictable markets;
- Focus on eliminating all types of waste across the supply chain and guiding supply chain processes to create value.

As seen above there are several major differences but we have considered two differences between Lean supply chain approach and typical supply chain's strategies that are very important and merit further discussion.

In typical supply chain strategies, forecast is based on product purchase to minimize all costs, while Lean seeks to create flexible procedures that are able to respond to any change in customer's needs. Lean's approach is not perfect because of forecast error, which requires constant update through the analysis of the continuous flow of sold stock (Coleman & McGowan, 2010). Any delay or problem that affects flow is worth studying for possible improvement opportunities.

Another difference between both approaches, is that the supply chain model has a cost saving perspective on manufacturing and delivering a product/service to a customer, while Lean focuses on value and waste that exist along the supply chain (Behrouzi & Wong, 2011).

Although both approaches share many features, their goals are very different and herein lays the advantage of the lean supply chain.

2.5.3. Implementation

Regarding implementation, Lean supply chain management's first step is to gradually eliminate all waste occurrences (Pinto, 2010). The methods for waste removal have been previously explained in sub-chapter 2.2.2. Pinto (2010) suggests a list of actions a company should take into consideration in order to implement a Lean supply chain:

- To understand that lean thinking is a continuous improvement process focused on eliminating waste and creating value to the end-customer;
- To identify and understand the effect's root-cause not its symptoms;
- To investigate why products aren't flowing consistently and in a more predictable manner in the supply chain;
- To position the inventory in the correct distribution centers. The right stock in the wrong location will result in unnecessary displacements and extra time and costs;
- To analyze the supply chain as a whole and to measure its performance continuously;
- To create a multidisciplinary team to move forward with the implementation, which has the support of management;
- To assess the possibilities of standardizing without compromising order personalization by customers;
- To recognize outsourcing's feasibility as a facilitator when responding to changes and demands of the market;
- To collaborate with suppliers and clients, trying to establish beneficial long-term relationships.

As can be seen in the list above, lean has several actions that a company must undertake in order to fully apply the philosophy to its supply chain. It is not an easy process but the benefits outweigh the disadvantages considerably.

2.5.4. Lean Distribution

> "Lean Distribution breaks the forecast accuracy barrier to improving customer service and profit with flawless execution of simplified operating processes." (Zylstra, 2005)

In the existing economic situation it has become increasingly difficult to forecast demand, as such cost reductions are harder to execute and with a growing competition, finding a location with the lowest manufacturing costs is crucial for global distributors. Lean distribution can be the correct approach to solve these problems based on its simplicity, flexibility and market orientation.

Lean's tools and techniques are applied to: simplify and increase the speed of the flow of materials, decrease the number of mistakes, eliminate unnecessary handling of inventory, maximize facility usage and improve inventory management. This can be done to help distribution companies operate at maximum efficiency, surpass the customer's expectation and increase profitability.

We now present benefits of lean distribution according to Reichhart & Holweg (2007):

- Decrease of finished products inventory;

- Decrease of model change-over times by decreasing timings of product discontinuation;
- Reduction of delivery lead times for specific customer orders;
- Increase of revenue per unit;
- Increase of customer satisfaction and brand image.

Although lean distribution can have high implementation costs, these can be overlooked by the profits made in the long term.

The brief reference to lean distribution is very important when considering unique situations, which will be explained in Chapter 4 and the conclusions of this dissertation. This approach is very appealing for manufacturing and distribution companies and thus it is worthy of consideration in the discussion of this dissertation.

2.6. Lean performance measures

As stated before, companies should assess their existing performance measures and this can be done through the application of performance measures. If we consider the application of the lean philosophy to an industry or company, than the performance measures used should be related to lean. Also, as Lean is based upon continuous improvement, it is important to identify and have performance measures to evaluate this component.

Performance measures are crucial to judge and evaluate if corrective actions are working out by comparing past performance with the existing one. This type of evaluation should be done monthly, weekly if possible and employees should have access to some of this data, because this helps the continuous improvement process. The result of performance analysis is better information, which a company can use to base its decisions upon.

In the literature review we discovered across several authors that many terms were used for the same purpose. We find it is necessary to dispel any doubts regarding performance measures synonyms. In order to help solve this problem we present the three most used terms discovered, when collecting data about performance measures. According to Ragland (1995) the terms can mean:

- Measure – determines or analyzes through comparison to a standard. It can be a standard or unit of measurement;
- Metric – quantifies a measure of a certain attribute that a system, component or process has. It is a calculated or combined indicator based upon two or more measures;
- Indicator – measures values against a baseline or expected results.

After clearing possible misconceptions because of the different definitions regarding performance measures, we now help defining what a lean performance measure is. Lean metrics can be defined as vital elements to the success of the lean manufacturing approach because they lead an organization on its path of lean transformation. Lean metrics consist of visible performance measures, targeted improvement, team reward and recognition (Feld, 2001 *apud* Khadem, Ali, & Seifoddini, 2008).

In order to obtain lean performance measures that can be used for the goal of this dissertation, we have reviewed performance measures of five different authors. This will be the groundwork for the selection of lean performance measures to be included in the survey used for the case study (sub-chapter 4.4).

Firstly Behrouzi & Wong (2011) who identified 148 performance measures through their analysis of various literatures. After they reviewed the literature, a panel of experts selected and filtered the most important and Lean-related measures resulting in 28 measures. The following characteristics were considered for the selection process:

- Accessibility;
- Measurability;
- Alignment of supply chain strategies and company goals;
- Importance and relationship to lean components (waste elimination, JIT and flexibility);
- Mix of supplier, manufacturer and client related measures;
- Financial and non-financial measures.

The 28 measures selected, which are related to lean are presented in Table 2.3:

Table 2.3 – Selected measures
Source: (Behrouzi & Wong, 2011)

1	Supplier rejection rate	15	Percentage of reworks
2	Percentage of standardized processes	16	Manufacturing cost per unit (repeated by Gurumurthy)
3	Labor value added productivity	17	Supplier volume flexibility
4	Customer delivery lead time (repeated by Gurumurthy)	18	Supplier product-mix flexibility
5	Percentage of total value-added time (repeated by Gurumurthy)	19	On-time delivery by suppliers
6	Setup, unscheduled and idle time	20	Warranty costs (repeated by Gurumurthy)
7	Average freight cost per unit	21	Defect rates of production
8	On-time delivery to customers (repeated by Gurumurthy)	22	Cost of energy
9	Customer complaints	23	Perfect order fulfillment by suppliers
10	Customer rejection rate	24	Supplier delivery lead time (repeated by Gurumurthy)
11	Total inventory	25	On-time production
12	Supplier delivery flexibility	26	Perfect order fulfillment to customers
13	Manufacturer delivery flexibility	27	Manufacturer volume flexibility
14	Defect rate of raw materials	28	Manufacturer product-mix flexibility

After computing values, the authors divided the 28 measures into four categories: quality, cost, flexibility and reliability.

Shah & Ward (2007) identified 48 practices/tools related to the environment close to where lean manufacturing happens. Seven practices were eliminated in a filtration process phase, resulting in a total of 42 practices, which were divided into ten categories. The practices/tools and according categories are presented below in Table 2.4:

Table 2.4 – Performance measures related to operational space near lean manufacturing

Source: (Shah & Ward, 2007)

Item number	**Item Label**
Suppfeed_01	We are in frequent contact with suppliers
Suppfeed_04	We give our suppliers feedback on quality and delivery performance
Suppfeed_05	We strive to establish long-term relationship with our suppliers
SuppJIT_01	Suppliers help in the development process of new products
SuppJIT_02	Key suppliers deliver to the plant on JIT basis
SuppJIT_03	Existence of supplier certification program
Suppdevt_01	Suppliers are contractually committed to annual cost reductions
Suppdevt_02	Key suppliers are based near the plant
Suppdevt_03	Existence of corporate level communication regarding important issues with key suppliers
Suppdevt_04	Action is undertaken to reduce the number of suppliers in each category
Suppdevt_05	Key suppliers manage our inventory
Suppdevt_06	Suppliers are evaluated on total price and not total cost per unit price
Custinv_01	Regular close contact with our clients
Custinv_03	Clients give us feedback on quality and delivery performance
Custinv_04	Clients are actively involved in existing and future product offerings
Custinv_05	Clients are directly involved in existing and future product offerings
Custinv_06	Clients regularly share existing and future demand information with marketing branch
Pull_01	Production is “pulled” by shipment/expedition of finished products
Pull_02	Production at stations is “pulled” by the existing demand of the succeeding station
Pull_03	Usage of “pull” production system
Pull_04	Usage of *Kanban*, squares or containers of signals for production control
Flow_01	Products are categorized into groups/families with similar processing requirements
Flow_02	Products are categorized into groups/families with similar routing requirements
Flow_03	Equipment/machinery is grouped to produce a continuous flow of families of products
Flow_04	Families of products define our factory layout
Setup_01	Our employees practice setups to decrease the required time
Setup_02	We are working to reduce setup times in our plant

Setup_03	We have low setup times of equipment in our plant
SPC_01	Great number of equipment/processes on the shop floor are under SPC
SPC_02	Great usage of statistical techniques to decrease process variance
SPC_03	Charts showing defect rates are used as tools on the shop floor
SPC_04	Usage of fishbone type diagrams to identify causes of quality problems
SPC_05	We do process capability studies before product launch
Empinv_01	Shop floor employees are crucial to problem solving teams
Empinv_02	Shop floor employees drive suggestion programs
Empinv_03	Shop floor employees lead product/process improvement efforts
Empinv_04	Shop floor employees undertake cross functional training
TPM_01	Every day we dedicate a portion to planned equipment maintenance relative activities
TPM_02	Equipment is maintained regularly
TPM_03	Records of equipment maintenance related activities are kept
TPM_04	Maintenance records are posted on the shop floor to share with employees

. The categories represent:

- SUPPFEED (supplier feedback) – performance feedback to suppliers;
- SUPPJIT (JIT delivery by suppliers) – guarantees suppliers deliver the right quantity, at the right time and place;
- SUPPDEVT (supplier development) – develop suppliers so they are more involved in the manufacturing process;
- CUSTINV (customer involvement) – focus on the company's clients and their requirements;
- PULL (pull) – helps JIT production with *Kanban*, tells when to stop or start manufacturing;
- FLOW (continuous flow) – creates processes that enable continuous flow of products;
- SETUP (set up time reduction) – reduces process downtime between product changeovers;
- TPM (total productive/preventive maintenance) – addresses equipment downtime to get the highest equipment availability;
- SPC (statistical processes control) – guarantees the processes won't manufacture defective units for the succeeding process;
- EMPINV (employee involvement) – employee's role in problem solving.

Gurumurthy & Kodali (2009) identified a set of measures related to lean manufacturing. This set is presented in Table 2.5:

Table 2.5 – Performance measures related to lean manufacturing
Source: (Gurumurthy & Kodali, 2009)

Performance measures of Lean Manufacturing			
1	Scrap and rework costs	46	Percentage of defective parts adjusted by production line workers

2	Manufacturing cost per unit (repeated by Behrouzi & Wong)	47	Percentage of products accepted as good without inspection
3	Value of work in process relative to sales	48	Percentage of manufacturing process under statistical control
4	Total productive floor space of overall space	49	Percentage of preventive maintenance over total maintenance
5	Reduction in overall plant investment	50	Number of *Kanbans*
6	Gross annual profit	51	Throughput time or manufacturing lead time
7	Total sales	52	Work-in-process inventory (WIP)
8	Reduced product cost or price	53	Setup time
9	Reduced inventory investment	54	Finished goods inventory
10	Warranty cost (repeated by Behrouzi & Wong)	55	Production capacity
11	Cost of poor quality	56	Batch size (average)
12	Reduced purchased cost	57	Length of product runs
13	Increase in revenue	58	Percentage of production equipment that is computer integrated or automated
14	Number of employees	59	Increased flexibility
15	PPM defective products shipped to customer (parts per million)	60	Number of mixed models in a line
16	Customer lead time (repeated by Behrouzi & Wong)	61	Raw material inventory
17	*Takt* time	62	Labour productivity
18	Rate of customer returns	63	Value added time (repeated by Behrouzi & Wong)
19	Number of new products introduced	64	Non-value added time
20	Time to market for new products	65	Number of inventory rotations
21	Improved time-based competitiveness	66	Equipment usage
22	Use of visual management or visual aids	67	Percentage of unscheduled downtime
23	Number of certified suppliers	68	Increase in productivity
24	Average distance between the supplier and manufacturer	69	Labour utilization
25	Percentage of parts delivered directly to the point of use from supplier without incoming inspection or storage	70	Ratio of indirect labour to direct labour
26	Number of sole sourcing suppliers	71	Utilization of capacity
27	Number of suggestions made to suppliers	72	Frequency of preventive maintenance

28	Average number of suppliers for the most critical parts	73	Level of housekeeping (poor/good/excellent)
29	Level of integration between suppliers delivery and the company's production information systems	74	Increase in production volume
30	Percentage of parts co-designed with suppliers	75	Number of shifts
31	Supplier or delivery lead time (repeated by Behrouzi & Wong)	76	Production rate
32	Percentage on time delivery (repeated by Behrouzi & Wong)	77	Overtime
33	Frequency of the deliveries	78	Improved equipment efficiency
34	Number of suppliers	79	Employee turnover rate
35	Number of years a supplier is linked to the manufacturer	80	Reduction in number of employees
36	Container size	81	Percentage of parts delivered JIT between sections in the production line
37	Penalties regarding short quantity	82	Percentage of people involved in stopping the line due to problems
38	Adherence to schedule	83	Number of teams
39	Percentage of procedures which are written or documented in the company	84	Percentage of employees working in teams
40	Amount (h) of training given to newly employed personnel	85	Reduction in direct labour
41	Number of suggestions per employee per year	86	Reduction in indirect labour
42	Percentage of employees cross trained to perform three or more jobs	87	Number of awards and rewards given to workers
43	Percentage of inspection carried out by autonomous defect control	88	Time spent on engineering changes
44	First pass yield	89	Number of total parts in bill of materials (BOM)
45	Manufacturing cycle time	90	Percentage of common or standardized parts

Sánchez & Pérez (2001) created a lean manufacturing checklist. The checklist has an integrated approach and is divided into six groups of indicators, where each group belongs to lean practices that help improve the company's performance.

It is advised that companies don't try to implement all groups simultaneously, but instead step by step. Each indicator has been created with the purpose of being more quantitative than qualitative, simple to understand and to use. Each group is described in the tables below:

- Elimination of zero-value activities – the first place usually targeted is the manufacturing area, so this check-list is relative to the manufacturing area (Table 2.6).

Table 2.6 – Lean manufacturing indicators of zero-value activities elimination
Source: (Sánchez & Pérez, 2001)

Definition	Change
Percentage of common parts in company products	A
Value of work in progress relative to sales	B
Inventory rotation	A
Number of times and distance parts are transported (R)	B
Amount of time needed for die changes	B
Percentage of preventive maintenance over total maintenance	A

Note: A – the indicator should increase to progress to lean manufacturing; B – the indicator should decrease to progress to lean manufacturing

- Continuous improvement – requires participation of employees and support of management, improvement teams need to be created and employees must have specific training (Table 2.7).

Table 2.7 – Lean manufacturing indicators of continuous improvement
Source: (Sánchez & Pérez, 2001)

Definition	Change
Number of suggestions per employee per year (R)	A
Percentage of implemented suggestions (R)	A
Savings and/or benefits from suggestions	A
Percentage of inspection carried out by autonomous defect control (R)	A
Percentage of defective parts adjusted by production line workers	A
Percentage of time machines are standing due to malfunction (R)	B
Value of scrap and rework relative to sales	B
Number of people dedicated primarily to quality control	B

Note: A – the indicator should increase to progress to lean manufacturing; B – the indicator should decrease to progress to lean manufacturing

- Multifunctional teams – helps task rotation and flexibility respond to changes in manufacturing (Table 2.8).

Table 2.8 – Lean manufacturing indicators of multifunctional teams
Source: (Sánchez & Pérez, 2001)

Definition	Change
Percentage of employees working in teams	A
Number and percentage of tasks performed by the teams (R)	A
Percentage of employees rotating tasks (R)	A
Average frequency of task rotation	A

Percentage of team leaders that have been elected by their own team co-workers	A

Note: A – the indicator should increase to progress to lean manufacturing

- JIT production and delivery – delivery of parts in the required quantity and at the right time (Table 2.9).

Table 2.9 – Lean manufacturing indicators of JIT production and delivery
Source: (Sánchez & Pérez, 2001)

Definition	Change
Lead time of customers' orders (R)	B
Percentage of parts delivered just-in-time by the suppliers	A
Level of integration between supplier's delivery and the company's production information system	A
Percentage of parts delivered just-in-time between sections of the production line	A
Production and delivery lot sizes (R)	B

Note: A – the indicator should increase to progress to lean manufacturing; B – the indicator should decrease to progress to lean manufacturing

- Integration of suppliers – is a lean feature that has influence in departments such as R&D and logistics (Table 2.10).

Table 2.10 – Lean manufacturing indicators of supplier's integration
Source: (Sánchez & Pérez, 2001)

Definition	Change
Percentage of parts co-designed with suppliers	A
Number of suggestions made to suppliers	A
Frequency of suppliers technicians visit the company	A
Frequency of company's suppliers are visited by technicians	A
Percentage of documents shared with suppliers by intranets or electronic data interchange	A
Average length contract with critical suppliers (most critical)	A
Average number of suppliers in critical parts (most critical)	B

Note: A – the indicator should increase to progress to lean manufacturing; B – the indicator should decrease to progress to lean manufacturing

- Flexible information system – should allow different groups of machines to operate and integrate with the production planning department. Delivering useful information to manufacturing line employees (Sánchez & Pérez, 2001) (Table 2.11).

Table 2.11 – Lean manufacturing indicators of flexible information system
Source: (Sánchez & Pérez, 2001)

Definition	Change
Frequency that information is given to employees (R)	A

Number of informative meetings between top management and employees	A
Percentage of procedures recorded in writing (R)	A
Percentage of production equipment which is integrated	A
Number of decisions made by employees without supervisory control	A

Note: A – the indicator should increase to progress to lean manufacturing

After reviewing the five tables of Sánchez & Pérez, we have detected that some performance measures have been repeated by the others authors we have studied. These performance measures have been marked with an (R).

Finally, Manotas Duque & Rivera Cadavid (2007) present a set of five improvement dimensions, each containing several indicators that provide a picture of the evolution of the company's manufacturing line and processes. The five dimensions and corresponding indicators are shown in Table 2.12:

Table 2.12 – Five improvement dimensions' indicators
Source: (Manotas Duque & Rivera Cadavid, 2007)

Indicators				
Elimination of waste	**Continuous improvement**	**Continuous flow and pull-driven systems**	**Multifunctional teams**	**Information systems**
WIP	Number of suggestions per employee per year (repeated by Sánchez & Pérez)	Lot sizes (average for each product) (repeated by Sánchez & Pérez)	Autonomous control (% of quality inspection done by the team) (repeated by Sánchez & Pérez)	Frequency that information is given to employees (repeated by Sánchez & Pérez)
Setup time	Percentage of suggestions that get implemented (repeated by Sánchez & Pérez)	Order flow time (time spent by an order in the shop floor)	Work team task content (% of tasks required to make the product, done by the team) (repeated by Sánchez & Pérez)	Percentage of procedures that are documented (repeated by Sánchez & Pérez)
Machine downtime (repeated by Sánchez & Pérez)	Scrap (% of products to be scrapped)	Order lead time (time from placement of the order to its delivery) (repeated by Sánchez & Pérez)	Cross training (number of skills needed in a team)	Frequency that line or cell progress boards are updated

Transportation (number of parts [trips]*distance) (repeated by Sánchez & Pérez)	Rework (% of parts that need rework)	Pulling processes (% of line processes that pull from predecessors)	Number of employees capable of assignment rotation (repeated by Sánchez & Pérez)	-
Space usage	-	Pull value (% of the total annual value or throughput of the system that is scheduled through pull mechanisms)	-	-

Upon reviewing Table 2.12's indicators, we have found that some of these have already been presented by the fourth authors, Sánchez and Pérez. These have been marked as repeated by Sánchez & Pérez.

The collection of the performance of the five authors gives us a wide selection of performance measures to be used at a further stage (sub-chapter 4.3).

We have finished the literature revision that will provide the theoretical background for the practical part of this dissertation.

3. METHODOLOGY

> “What the case study does represent is a research strategy, to be likened to an experiment, a history, or a simulation, which may be considered alternative research strategies.” (Yin, 1981)

It is crucial to use the correct structure and research techniques for the practical part of any study performed. Case studies are great tools to apply when dealing with situations that require large amounts of data and complex data. It is useful to have a structure and techniques that facilitate the creation of the case study and thus simplify complicated proceedings into an easy manner.

We have decided to build a case study in order to explore and discover important results considering the application of lean in the Wood-Plastic Composite industry and to try to answer the question posed at the beginning of the study (see sub-chapter 3.3). But first we need to understand what a case study is and what it does.

The case study focuses on a number of issues in an existing situation; most times it will be used for an organization or a department or area of an organization. A few applications of the case study are (Boateng, 2009):

- To describe a set of specific conditions, from which organizations can learn from;
- To demonstrate a certain theory or conceptual framework by using a particular example or testing how a particular group of conditions can generate certain results;
- To define an uncommon occurrence or an unusual organization.

Due to its application in real life settings the case study is a powerful analysis tool. It is very good at addressing “how” and “why” questions because of the range of evidence it employs. The case study is part of a variety of techniques which are employed in business studies, management studies, experiments, surveys and historical reviews.

Before introducing the collecting and analyzing processes of the case study, it is important to learn how to structure a case study’s report. Boateng (2009) lists six different types of case study structure:

- Linear analytic – adopts the researcher’s viewpoint addressing the issues being studied: literature review, methods used, discoveries, and conclusions;
- Comparative – the case study is observed from different perspectives in order to give the best explanation;
- Chronological – case study’s proof is presented in chronological order;
- Theory-building – case study is created according to a theory;
- Suspense – opposite of the analytical option, the end-result is given first and explained after;

- Unsequenced – structure has no specific logic.

Regarding case study structure, we have applied the first option. Adopting the researcher's viewpoint and discussing the issues we have studied, which is explained in sub-chapter 3.3.

It is useful to know the range of options of case study structure one has to choose when building a case study. After choosing the case study's structure, we should look into the different methods available to collect data. There are several ways to collect data and there should always be more than one source in order to have reliable data. It is advised to use more than one method to collect data, so that this is as accurate as possible. Some of the data collecting methods are (*Idem. Ibidem*):

- Documentation – provided by the organization such as: emails, press releases and internal reports. Or provided by secondary sources like published studies and market reports;
- Archival records – usually from the organization's databases such as: customer records, organization charts and personal records or a mix of these;
- Interviews – particularly with key informants, interviews can be open or the interviewer can have pre-selected questions;
- Surveys – used for a specific population sample or when the number of people to be interviewed is too large;
- Direct observation – watching workers do real time tasks;
- Participant observation – person watching is also involved in the process;
- Physical artifacts – physical proof of the case study.

After collecting data it is important to analyze it, problems that are related to the analysis can appear. These problems have to be minimized, and there are three techniques for decreasing problems created when analyzing data according to (Yin, 1981):

- Distinguishing note-taking from narrative taking – it is usual for analysts to develop narratives out of individual interviews, meeting or other events; these are wasteful unless required. Narratives should be based on important topics of the case study and evidence should be from different data elements;

- Tabulating Meaningful Events – addresses the problems of analyzing quantitative data. Quantitative data is coded and tabulated so it can be integrated with qualitative data during the narrative. Drawbacks happen when analysts use categories that are too small or large;

- Building Explanations – important when trying to explain an occurrence. An explanatory case study consists of: accurate rendition of case facts, consideration of alternative explanations of the facts and a conclusion based on the explanation that is the most consistent with facts.

3.1. Validity

> "The degree to which an instrument indeed measures what it purports to evaluate." (Raykov, 2011)

It is important to understand if what one is measuring, is being done correctly. As such we have enlisted the help of the validity test, which is divided into discriminant and convergent validity. These two types of validity will now be explained.

Convergent validity verifies that constructs which are expected to be related, are in fact related. And discriminant validity verifies that constructs that aren't expected to be related, are not related at all. If the study's object has convergent and discriminant validity than it can be viewed as having excellent construct validity (Shuttleworth, 2009).

Discriminant validity and construct validity will not be discussed further as it isn't the objective of this study to know if items that aren't related are truly not related. This is an opportunity to further this study.

3.2. Reliability

> "...measurements are reliable to the extent that they are repeatable and that any random influence which tends to make measurements different from occasion to occasion or circumstance to circumstance is a source of measurement error." (Nunnally, 1978)

Estimation of Reliability

As defined by Nunnally, the internal consistency "Estimates of reliability based on the average correlation among items within a test are said to concern the internal consistency". The alpha coefficient is a tool used to calculate reliability based on internal consistency and demonstrates how well items measure their category.

Regarding the alpha coefficient previously mentioned, it is designated Cronbach-alpha and was developed by Lee Cronbach in 1951. It ranges from 0 to 1 and can be employed to determine the reliability of scaled surveys such as the Likert scale. The higher the value of the coefficient is, the more reliable the scale will be. A value is considered satisfactory if it belongs to the interval of 0.7 to 0.95 (Tavakol & Dennick, 2011).

Statistical results can be obtained through computer softwares, such as SPSS that calculates the Cronbach-alpha coefficient among others. Another useful tool is the Cronbach-alpha coefficient if item deleted, which determines what happens to the alpha coefficient if you delete an item. It helps users understand which the most important items are, because the Cronbach-alpha's value will decrease when these items are eliminated. The method is described by (Gliem, 2003) as:

> Alpha if Item Deleted — "This is probably the most important column in the table. This represents the scale's Cronbach-alpha reliability coefficient for internal consistency if the individual item is removed from the scale (...). This value is then compared to the Alpha coefficient value at the bottom of the table to see if one wants to delete the item." (Gliem, 2003)

After discussing the theoretical concepts of the case study, we will now discuss in greater detail what has been done in the dissertation regarding methods used with the help of visual aids.

3.3. Procedures

The methodology employed is based upon Yin's methods and techniques. In respect to the case study's structure, Yin's method of linear analytic approach, which adopts the researcher's viewpoint, is used. It addresses the literature review, methods used, discoveries, and conclusions. Regarding Yin's research techniques, the techniques employed in this case study are documentation (provided by Tecnodeck), surveys and interviews.

Concerning data analysis, Yin proposes methods that allow for the decrease in problems created during the analysis. We have chosen to go with the Building Explanations method, to try to explain the facts and arrive at a conclusion that is consistent with the facts (Boateng, 2009).

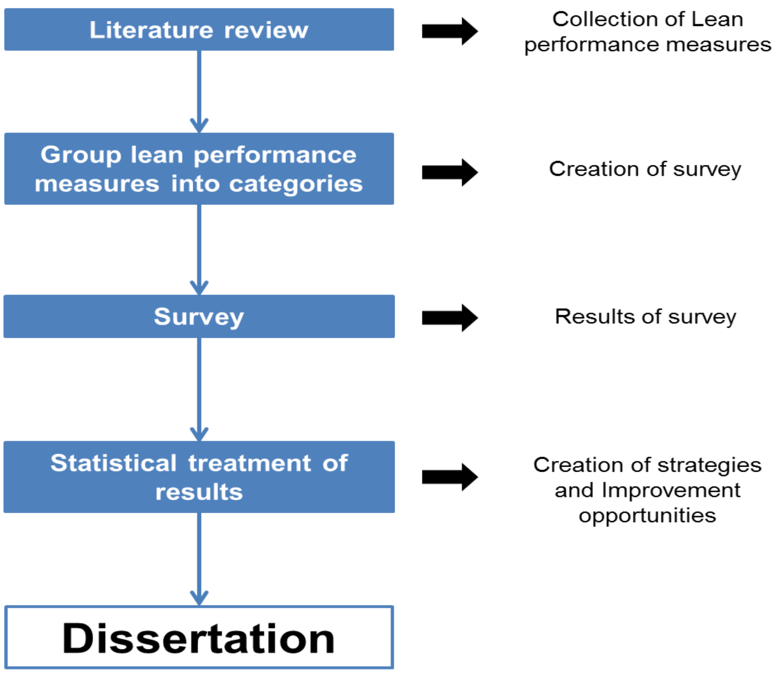

Figure 3.1 – Methodology of dissertation

Before handing out the surveys to the employees, several strategic performance analysis tools were applied, such as: SWOT analysis (Table 4.1), PEST analysis, BCG Matrix (Figure 4.5), Porter's Five Forces (Figure 4.6) and Balanced Scorecard (Figure 4.7). Although there are several other strategic tools we could apply, we have chosen these to help provide a strategic picture of Tecnodeck's situation.

The strategic tools were applied based upon information obtained from interviews with management and research and are thus different from the statistical analysis, which is based on the survey's results and interviews with management. Although the end-result may be similar, it has not been developed upon the same data parameters.

We have decided to employ the term lean performance measures after presenting the three most used terms of several authors. We now present step by step each action taken for the creation of survey that was based on the collected lean performance measures:

1) After collecting the lean performance measures through a revision of scientific literature, we grouped the same performance measures from different authors in Table 4.2.

2) After this, we proceeded to filter the most common performance measures across the different authors and group them into four categories: cost, time, flexibility and quality. These categories are a preliminary approach for supply chain measures and thus constitute a valid basis from which to begin. They appear in Table 4.3 - Performance Measures Categorization**.**

3) After completing this table we had to filter it again, considering there wasn't major production in Portugal coupled with Tecnodeck's personnel input. As a result a few lean performance measures related to manufacturing were replaced.

4) Afterwards we created a survey online, with the help of Google Docs that was delivered to the Tecnodeck personnel. We decided that the survey should be divided into five categories, four categories containing the Lean performance measures identified during the literature review, and we added a fifth category related to critical activities of Tecnodeck that were identified by Tecnodeck personnel. The last category was used to measure the importance given to each of the three activities it contains and most importantly as another connection to the lean philosophy, since these are value-adding activities.

   In the survey, users were asked to quantify each performance measure according to their judgment regarding the *Likert* scale, 1 to 5 (1 = very unimportant and 5 = very important). Every question in the survey was mandatory except one, regarding occupation. And at the end of the survey, users could offer suggestions but none was received.

After discussing the survey's development we now discuss the statistical treatment of its results, which were treated with SPSS statistical software:

5) Before being treated statistically, the initial results were commented and special and unexpected results were commented in greater detail.
   5.1) Firstly, demographic graphs were made regarding Tecnodeck's staff (Figure 4.9 - 4.13).
   5.2) Secondly, means, standard deviations, confidence intervals and upper and lower bounds were calculated for each item (Table 4.5 - 4.6).
   5.3) Thirdly, we made the graphs for Time's four items not created according to the *Likert* scale (Figure 4.11 - 4.16).
   5.4) Fourthly we created the standardized mean results of each category that help identify the importance given to each category (Table 4.7).
   5.5) Fifthly, Comparison analysis graphs were made for an easy visual overview of the five categories importance (Figure 4.15 - 4.22).
   5.6) Sixthly, a highest and lowest item per category table was created in order to easily identify the most and less important items of each category (Table 4.8).
   5.7) Finally, a Top Ten item table was created to easily demonstrate the most important items to the users (Table 4.9).

6) The first part of the statistical software's application was to evaluate the results for internal consistency reliability, which was done by the Cronbach-alpha coefficient (Table 4.10). After which, the "Alpha if Item Deleted" method was applied (Table 4.11). As it happened in the previous test, the four items of the Time category that were not created according to the *Likert* scale were not included in the reliability test.

7) In the second part of the statistical software's application, results were tested for convergent validity (discriminant validity was not performed). Firstly with the creation of a correlation matrix for all categories (Table 4.12). Secondly, we created a correlation matrix for each category's items (Table 4.13 - 4.17). The Pearson correlation could also be applied but the correlation matrix is simpler and performs the same task. Thirdly we created a table with the highest and lowest correlation scores of each category (Table 4.18) and another table with the quantity of positive, negative and zero correlation scores to help determine convergent validity (Table 4.19). Four items (belonging to the Time category) weren't created according to the *Likert* scale and thus weren't tested for convergent validity. Since testing for convergent validity is only part of testing a construct's validity, the task of testing for a construct's validity remains incomplete.

The purpose of the first test (reliability) is to understand if the survey has provided consistent and reliable results, which measure their category. The purpose of the second test (convergent validity) is to understand if the performance measures used in the survey actually measure their corresponding category and thus if they were correctly assigned to it.

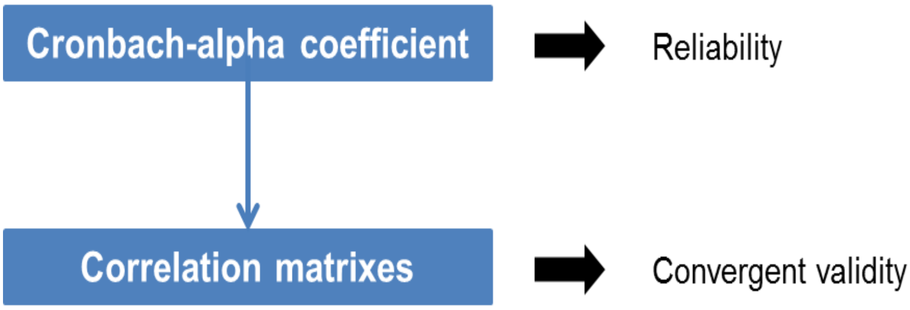

Figure 3.2 – Statistical treatment

The final form of retrieved data is interviews with management. These are conducted in order to better understand management's comprehension, knowledge and expectations of applying the lean philosophy.

After the interviews with Tecnodeck's management, we present Table 4.20 that contains the suggested improvement opportunities for each category. Considering the survey's results and the interviews with management especially regarding areas of improvement, we suggested improvement opportunities that could take advantage of the two areas management identified as having improvement opportunities (handling and stock management) and to consider the worst statistical scores: Rework (Q1), Batch size (F1) and Reduction of repair cost (C7).

We found it important to review Lean distribution's literature and present its definition and advantages. Because there isn't at the moment a manufacturing line of Tecnodeck in Portugal, lean distribution will not be applied to the case study. But if Tecnodeck decides to build a manufacturing line in Portugal, it will be an important philosophy to consider applying.

Considering lean performance measures' data, we have created three strategies based upon Porter's generic strategies. Although there are other basic strategies, such as Treacy and Wiersema, as stated before we have chosen Porter's strategies because of their market orientation. The developed strategies take into account the findings made during the statistical treatment, interviews with management and the improvement opportunities discovered.

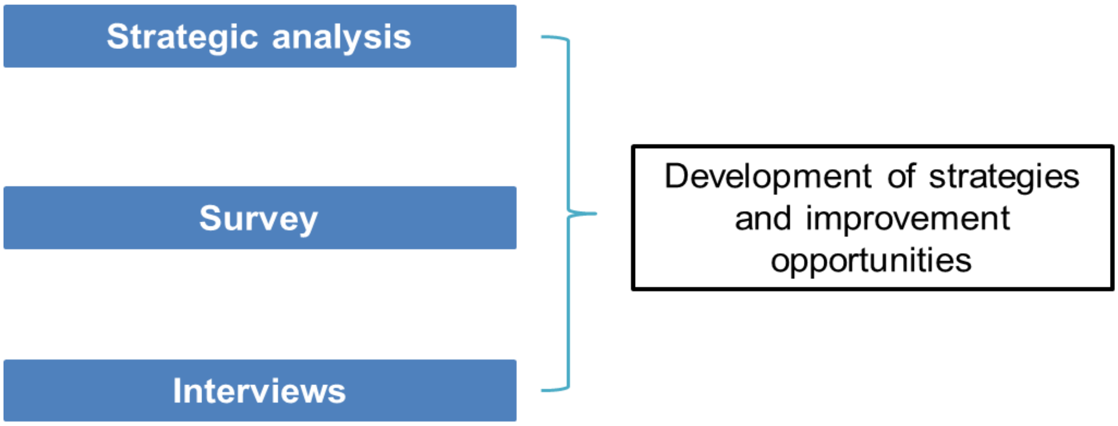

Figure 3.3 – Dissertation results

Finally after the survey results, interviews with management, discovery of improvement opportunities and the creation of the strategies for Portugal, Italy and Belgium, we developed the conclusion of this dissertation. In the conclusion we have tried to answer the research question: “How does the wood-plastic composite industry value the identified lean performance measures?” By considering that the importance given to the performance measures by the case study’s company’s staff can be representative of the industry itself. As the case study’s company is the market leader in the WPC industry and has been marketing the product for over a decade.

With the surveys’ results, we identified the most important categories, the most important performance measures and the worst performance measures according to both statistical tests and the importance attributed to each performance measure by Tecnodeck’s staff. We then suggested a few actions in order to increase the statistical tests scores, by replacing or rephrasing lean performance measures.

Further studies are suggested, firstly to develop a Lean procedure for the WPC industry. Secondly to perform a discriminant validity study of the identified lean performance measures in order to complete the construct’s validity analysis. Thirdly to develop and implement a lean strategy for Tecnodeck with the help of an experienced Lean user according to the survey’s results and the improvement opportunities discovered. Finally we suggest that Tecnodeck look into lean distribution if a manufacturing line is installed in Portugal, as Tecnodeck could greatly benefit from it.

4. RESULTS AND DISCUSSION OF THE CASE STUDY

4.1. Characterization of the case study

4.1.1. Definition, Features and Manufacturing process

> "Tecnodeck is exclusively designed for pedestrian use, in private and commercial-medium intensity applications."(Tecnodeck, 2012)

The wood-plastic composite industry is a relatively new industry in the Portuguese market and it has been steadily growing the last ten years. It has enjoyed some degree of success because of its durable, reliable and environmentally concerned products. They are an alternative to wood and can be recycled, having become an increasing popular choice. The WPC products have been previously introduced in other European countries such as Belgium, England and the Netherlands, where these products have been on the market for a longer period of time and are in greater demand from the average customer. The wood-plastic composite products have several applications:

- Building exteriors and interiors (façades, decking, window profiles and door frames);
- Various (furniture, outdoors, landscaping, gardens, marinas, automotive, etc.).

In a brief explanation, the product is manufactured by an extrusion process using wood residue and thermoplastic. Its manufacturing processes will obviously change according to each company but we have presented the basic manufacturing principle for the WPC product.
According to management the predicted global market applications of the WPC product is of two to three million tons. Regarding the Portuguese market, data for market value and profits are not available. Only the data of the market share of the leading company was possible to obtain from interviews with management of the case study's company.

The object of the case study is the Tecnodeck product that belongs to the company also named Tecnodeck. Tecnodeck operates in wood-plastic composite industry (WPC), which belongs to the *"Outro comércio por grosso de bens de consumo", n.e (Código 46494-R3 – CAE)* business.Tecnodeck's main activities include the development of wood and plastic composite materials. This type of materials is enjoying a rapid growth across Europe and Tecnodeck has been one of its pioneers. The product which is a complete docking system made of wood and plastic composite and Tecnodeck began marketing this product in 2004.

Tecnodeck uses wood residue mixed with thermoplastic to manufacture its product, which makes it a social and environmental aware product. Tecnodeck utilizes selected wood particles using a sophisticated technology that encapsulates them in thermoplastic thereby using the best qualities of wood with the resistance and durability of thermoplastic. This gives the Tecnodeck product a great resistance to atmospheric agents, the natural look of wood and spares the necessity for traditional and expensive treatments of oils and immunizers as used in pure wood. The thermoplastic used to manufacture the Tecnodeck product doesn't contain PVC and is the result of an advanced technology. Regarding quality standards, the Tecnodeck product is manufactured under the ISO 9001 standard, it has completed testing as a pavement by the TÜV Rheinland Institute and has been tested by LNEC (*Laboratório Nacional de Engenharia Civil*) in Portugal. The Tecnodeck company is currently implementing the CE marking quality system check in Portugal.

As for Tecnodeck's most important features, these are:

- Resistance to atmospheric agents (e.g.: UV rays);
- Resistance to fungi and insects (e.g.: bacterial);
- Doesn't crack or create splinters;
- Resistant to humidity and doesn't rot;
- Doesn't need maintenance with oils or immunizers;
- Doesn't contain harmful products to the environment;
- 100% recyclable;
- Valid alternative to exotic woods, thus protecting tropical forests;
- Higher density;
- Quality product surface finishing.

We find interesting to further explain some of Tecnodeck's features. Starting with the maintenance feature due to its importance in manufacturing industries, Tecnodeck is an acknowledged product that requires little or no maintenance. It has excellent resistance to atmospheric conditions which helps preserve natural resources and has been applied in various environments such as: landscaping, pools, spas, terraces, marinas, building's façades, balconies, railings, pool surroundings and garden decks. The Tecnodeck product is available in four different colors: tropical brown, sand brown, volcano black and colorado red. These can be seen at the company's website, http://www.tecnodeck.pt/pt/, which offers clients all the information they require and also provides online support manuals for clients to install the composite deck.

Figure 4.1 – “Tecnodeck ALU Panel”
Available at: (Tecnodeck, 2012)

After describing some of the product’s features and advantages, we will now discuss its origin, manufacturing process, lead times and applications.

Tecnodeck’s components are supplied by a Canadian company based in China, where their plant is located. But Tecnodeck also outsources components from Portuguese companies such as clips and fixing bolts. The Tecnodeck company has exclusivity rights of its product’s raw materials, having developed every part of the Tecnodeck product.

Regarding the manufacturing line in China, the plant has an extrusion process that is continuous and the design can be changed by changing the molds. There are common or standardized parts in the manufacturing process which helps save costs.

It is thus important to emphasize that Tecnodeck has no manufacturing line in Portugal. Its components come separated from China and are assembled together with other components manufactured or outsourced in Portugal. The plant in China can also ship worldwide if the client requires it, each container load from China averaging 1200m2. The average lead time (time from getting the order to delivery to the client) for the Tecnodeck product, ranges from 60 to 90 days and the average time to manufacture product to fill a container at the production facility is 4 weeks.

The previously mentioned features of the product were designed by the company, specifically to gain advantage in the market and differentiate the Tecnodeck product from its rivals. The end result is a product with added value for clients. The creation of value process for the Tecnodeck product happens at the final assembly at the client’s location where the product is installed and customized to the client’s orders. This is one of the major features that allow the study of this product from a Lean perspective. It is important to state that lean philosophy has not been applied to Tecnodeck’s processes previously.

4.1.2. Market and Clients

With the existing economic crisis in Portugal, companies are struggling because of the need to cut down on costs. Although Tecnodeck can be considered a high-end product, its market has grown and so has its popularity contrary to the existing economic situation trend.

Tecnodeck was the first company to market the wood-composite product in 2004, since then several companies have been created and disappeared. Tecnodeck exports to several countries: Argentina, Belgium, Chile, France, Germany, Greece, Hungary, Israel, Italy, Romania and Spain, and has distributors in Belgium and Italy. In Italy, Tecnodeck is represented by the *Sogimi* Group, their exclusive distributor, and their biggest rival is Greenwood (http://www.greenwood-venice.com/en/deck-colori.html).

Tecnodeck seeks to meet every customer's orders servicing architects, designers, among others, that privilege customization of products with emphasis on outward appearance, performance and exclusivity. This has resulted in Tecnodeck being used in large and high-profile projects like Giorgio Armani's Hotels Group in Dubai, Milan, Paris and New York. Quality and customer specification are two features that Tecnodeck privileges, which are also two features valued by lean.

After identifying an opportunity, Tecnodeck has opened an office in Belgium, Tecnodeck Benelux. The purpose is to assess the product's maturity in the Belgian and the surrounding markets, which also include: France, Luxembourg and the Netherlands. The goal is to organize a supply network to these three countries and monitor their markets.

4.1.3. Strategic objectives

Due to Tecnodeck's large market share in the Portuguese market, its current strategy is to expand its line of products. After careful research of the market demands and trends, Tecnodeck has created a new range of items like: pergolas, guard rails/ hand rails, flower pots, etc.

Regarding international markets, Italy is an emerging market for composite decks. It is the company's objective to consolidate its position and gain market share in the Italian market. Tecnodeck's existing market share in the Italian market is unknown, according to management. Whilst in Belgium, Tecnodeck had to hire personnel to introduce the product and its range of applications to potential clients while emphasizing the product's specifications, and finally to look for a distributor already operating in the market. Belgium's market for composite decks is more mature as it has had this type of product for a longer period; according to existing information, market share for composite deck in Belgium is unknown.

4.2. Performance analysis

After presenting and characterizing the WPC industry and the case study's company, Tecnodeck, we are going to evaluate the case study's company from a strategic planning perspective. Thus, in view of strategic planning and the creation of competitive advantage it is useful to apply the strategic tools suggested in the literature review (sub-chapter 2.2) in order to better understand the industry and the company; so that we can develop and suggest viable strategic plans which can lead to competitive advantage. We will begin with the strategic analysis of the environment and development of a strategy and only then proceed to the identification of the lean performance measures and their subsequent integration in a survey that can yield valuable data when regarding lean's application in the WPC industry.

The following performance analysis tools have been employed with knowledge of the market provided through research and meetings with management. The developed analyses are therefore based on the information obtained through interviews with management and research, and not based on the statistical results from the surveys. The statistical results will be commented further on (sub-chapter 4.4). We will now present the results for the analyses we introduced during the literature review, although we must mention that there exist many other tools that we could have used. As such we will apply four strategic analysis tools regarding the industry's environment: SWOT, PEST, BCG Matrix and Porter's Five Forces, and a last tool regarding the company's strategy, the Balanced Scorecard.

The following strategic tools have been applied in order to determine and assess the industry's environment and Tecnodeck's strategy. We are trying to form a picture with the advantages, disadvantages, threats and opportunities that exist in the WPC industry. After applying these four tools, we move on to analysing the company itself, its objectives and how best to accomplish these through the creation of the appropriate strategies.

4.2.1. SWOT Analysis

The first tool is the SWOT analysis which provides input on the company's environment. By analysing Tecnodeck, we are able to create its SWOT analysis diagram:

Table 4.1 – Tecnodeck's SWOT analysis diagram

SWOT Analysis	
Strengths (S)	**Weaknesses (W)**
• Innovative product • Quality of product	• Competitive market • Existence of substitute products

• Brand image • Various site applications (landscaping, pools, etc.) • Specified to customers' rigorous requirements • Retail distribution • Doesn't rot/ Impervious to rain • Recycled product/ Eco-friendly/ Viable alternative to wood products • Low or no maintenance required • Certified product ISO 9001 • International presence (Italy, Belgium, etc.) • Two suppliers for critical parts • Trendy product	• Large period of transporting product from factory(China) to Portugal • Needs large shipments to cover seasonal demand • Small flexibility on container sizes from Chinese plant (financially based) • Large lead times (60 to 90 days)
Opportunities (O)	**Threats (T)**
• New applications • International expansion • New manufacturing line in Portugal • Increase of market share at home and abroad • Possibility of becoming a trendy product abroad	• Loss of clients • New rivals • Economic crisis • Inventory shortage if transportation fails and/or outsourcing fails

By combining Strengths (S) and Opportunities (O) from Table 4.1, we are able to create strategies that are a match to the company's strengths such as:

- Innovative product (S) and various site applications (S) allied to new manufacturing line in Portugal (O). Can lead to a decrease in cost and increase of profit, based on decreasing transportation costs, exploiting existing markets and attracting prospective customers;
- Various site applications (S) and international presence (S) mixed with international expansion (O) and possibility of becoming a trendy product abroad (O), can increase the product's demand and profits through new and untapped markets;
- Retail distribution (S), various site applications (S) and two suppliers for critical parts (S) allied to an increase of market share (O) can become an effective strategy, if the product has a wider customer base to service;
- Quality of product (S) and valued features such as recycled product, eco-friendly, viable alternative to wood (S), doesn't rot/ impervious to rain (S) and low or no maintenance

required (S) can be very attractive in new markets. These strengths allied with International expansion (O) (that represents richer and larger markets) and new manufacturing line in Portugal (O) (that can help decrease lead times and transportation costs) will be a great help when entering new markets;

- Brand image (S), trendy product (S), certified product (S) and specified to customers' rigorous requirements (S) allied to new applications (O) can lead to an increase of market share in Portugal.

When mixing Weaknesses (W) and Opportunities (O) we can devise strategies that try to overcome weaknesses and seek opportunities:

- Competitive market (W) associated to new applications (O) and possibility of becoming trendy abroad (O) can help the company gain competitive advantage and thus create an edge over its competitors;
- Existence of substitute products (W) combined with possibility of becoming trendy abroad (O), increase of market share (O) and new applications (O) can help the company gain competitive advantage over substitute products;
- Small flexibility on container sizes (W) combined with a new manufacturing line in Portugal (O) can help increase flexibility and decrease costs (manufacturing, transportation, maintenance and inventory);
- Large lead times (W) with a new manufacturing line in Portugal (O) can help increase flexibility, and decrease transportation and manufacturing time;
- Large period of transporting product from factory (China) to Portugal (W) and needs for large shipments to cover seasonal demand (W) allied with a new manufacturing line in Portugal (O) can help decrease transportation costs and transportation time that itself helps more easily to cover demand.

Associating Strengths (S) to Threats (T) can create strategies that use the company's strengths to reduce vulnerability to threats:

- Recycled product/ eco-friendly (S), quality of product (S), low or no maintenance required (S), certified product (S) and trendy product (S) linked to economic crisis (T) and loss of clients (T). The product's popularity can help maintain the product's interest in demand despite the bad economic situation and loss of clients as new clients emerge;
- International presence (S), various site applications (S), doesn't rot/impervious to rain (S) and trendy product (S) mixed with loss of clients (T), economic crisis (T) and new rivals (T). The product's expansion to other countries can help battle some financial drawbacks due to the economic crisis and new rivals competing, by tapping into countries with more financial power, less established rivals and new clients;
- Two suppliers for critical parts (S) allied with inventory shortage if transportation fails (T) can help decrease the possibility of stock out and thus incur in great costs and increase of lead times;

- Retail distribution (S) and trendy product (S) combined with loss of clients (T) and new rivals (T) can help decrease the loss of clients and the influence of new rivals, through a wider availability of the product to a larger customer base. This can lead to an increase of profits by decreasing costs.

Combining Weaknesses (W) with Threats (T) can develop preventive strategies so that weaknesses don't increase the risk of threats:

- Combining existence of substitute products (W) with new rivals (T). It can be harder for new competitors to enter a market if there are substitute products. New rivals will find it difficult to make a profit. Thus new rivals have to distinguish themselves in order to obtain the customers preference;
- Competitive market (W) mixed with economic crisis (T) and new rivals (T). With a competitive market and an economic slowdown, it can be very hard on new rivals to operate. Companies have to reduce costs or offer better benefits to maintain their clients;
- Small flexibility on container size (W) and needs for large shipments to cover seasonal demand (W) combined with Inventory shortage if transportation/outsourcing fails (T) is a nightmare situation. Companies have to try and optimize their forecast, which is very difficult. This type of problem is difficult to foresee and even more difficult to solve;
- Large lead times (W) and large period of transporting product (W) linked to inventory shortage if transportation fails and/or outsourcing fails (T) is possibly one of the worst case scenarios. These situations can be avoided through well-developed channels of communication and if factory and outsourcing companies have safety stocks.

The strategies have been developed based on the mix of strategies seen in Figure 2.2, which include factors of the SWOT analysis diagram seen in Table 4.1. These strategies will try to help depict the company's environment.

4.2.2. PEST Analysis

To further analyze the company's environment, it is important to evaluate where the company operates, more specifically, the countries where Tecnodeck operates or has an interest in. This will be provided by the PEST analysis.

PEST analyses have been performed for three countries: Italy, Portugal and Belgium. A brief note is written about China at the end. These analyses intend to show the viability of investing or operating in each country.

Italy

Political-Legal

Italy is a republic and it is divided into 15 regions and 5 autonomous regions. Its political situation is finely balanced as the state bureaucracy is inefficient.

Italy’s tax laws are progressive, the higher the income the higher the tax. Italy has a free market because it is a common policy of European Union members. This policy also prohibits trade barriers between members. Thus Italian laws don’t present a great barrier of entry to new companies.

Some of Italy’s strong points regarding the political-legal aspect are (CenterforGlobalDevelopment, 2012a):

- The political risk insurance agency provides a wide coverage and screens potential projects for violations of human, environmental and labour rights;
- Employs tax treaties that prevent double taxation of corporate profits earned abroad.

Italy introduced significant measures to reduce its debt but it has re-entered recession and is expected to continue.

Economical

Italy is part of the G8 group, which is composed by the world’s leaders of industrialized countries. Italy has a diversified industrial economy that is divided between the industrialized north ruled by private companies and the south that is less-industrial, more agricultural, welfare-dependent and with a high unemployment rate. One of Italy’s economy drivers is the manufacture of high-quality consumer goods produced by small and medium-sized companies (TradingEconomics, 2012b).

Italy's major exports are: food, clothes, precision machinery, motor vehicles and chemicals. Its imports are mostly: chemicals, transport equipment, energy products, minerals and textiles. Italy has low tariffs on textiles and apparel, and imports large quantities of textiles from poorer countries. Its natural resources are marble, petroleum and it also has substantial natural gas reserves.

Italy’s GDP (Gross Domestic Product) has contracted and has been decreasing these last years. Summing up its current situation, Italy has been considered a non-growing and free market coupled with the current crisis, its buying power has diminished somewhat. This can be seen in Figure 4.2.

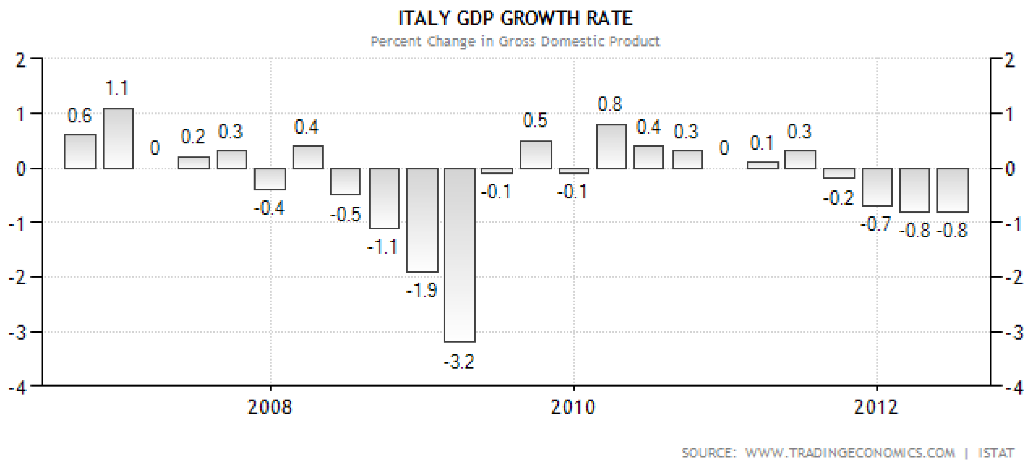

Figure 4.2 – Italy's GDP Growth Rate
Source: www.tradeingeconomics.com/ instituto nacional estatistica. Available at: (http://www.tradingeconomics.com/charts/italy-gdp-growth.png?s=itpirlqs)

Social ("ICT usage: households and individuals 2010,"):

- Population: 60.8 million;
- Unemployment rate: 10.7%;
- Literacy rate: 98% (total population);
- Population growth rate: 0.38%;
- Ethnicity: small clusters of Slovene-Italians in the north and Albanian and Greek-Italians in the south;
- Birth rate: 9.06 births/ 1000 people;
- Internet users: 35.8 million (2011);
- Computers owned: 57.6% of homes (2010);
- Outward appearance is important in society and family values are important to Italians.

Technological

Italy has a wide variety of network transportation: 130 airports, numerous ports in the South (important for the Mediterranean Sea traffic routes), 487 700km of roadways and 20 155km of railways.

Italy has become one of the world's leading producers of renewable energy, ranking 4th in solar and 6th in wind.

One of the disadvantages of Italy regarding technology is the small support from government for R&D. It spends 1% of its GDP in Research & Development.

Market perspectives

As was stated before, Tecnodeck has clients and rivals in Italy. Greenwood (http://www.greenwood-venice.com/en/deck-colori.html) is their biggest rival and the *Sogimi* Group is their exclusive distributor.

The *Sogimi* Group works in several areas: transformation of various types of plastic foam, sheets of plastic/aluminum composite for construction, architecture and of course Tecnodeck. It customizes products to fit the customer's demands.

Greenwood has a large experience in the plastic industry and is the leader of the extrusion of wood composite market. According to their website, it is Greenwood's mission to become Europe's leader in market and technology of composite wood.

Greenwood is thus a major rival to Tecnodeck and can present difficulties when trying to gain market share. Numbers regarding market share and market growth in Italy are not available.

Portugal

Political-Legal

Portugal is a republic and is divided into: 18 districts and 2 autonomous regions. Its judicial system is fairly independent but lacks efficiency. Portugal's immigration laws are complicated and with a high number of immigrants trying to obtain residence in the country. Labour laws exist for both temporary and non-temporary jobs. The minimum age required is 16.

Portugal has a free market due to the European Union's policy. This means there are no trade barriers among members. Its individual tax laws are progressive (the higher the salary the higher the tax).

Environmental laws consider noise control in several environments such as: residential areas, hospitals and schools.

Economical

Portugal belongs to the European Union and has become a diversified and increasingly service-based economy since joining it in 1986. Although the GDP grew in the 90's, since 2001 it has been decreasing, with 2010 being the exception, and in 2011 it fell again with the implementation of austerity measures. Due to low labor cost threats from the east, low competitiveness and growth prospects and a large public debt makes Portugal a threat to markets across Europe. Portugal's taxes and other revenues constitute 44.9% of its GDP (TradingEconomics, 2012c).

The north of Portugal contains most of its industries while the south is less-industrial and more agricultural, with a high unemployment rate and becoming increasingly deserted. The migration consists mainly of people from the south and interior, to the coast and centre of Portugal. Some of the Portuguese economy's drivers include: tourism, cork, wine and olive oil related industries, shoe related industries, sea associated industries and small start-ups of research and development.

Portugal has one of the lowest GDP per capita in Europe and one of the lowest average incomes in the European Union. This can be seen in Figure 4.3.

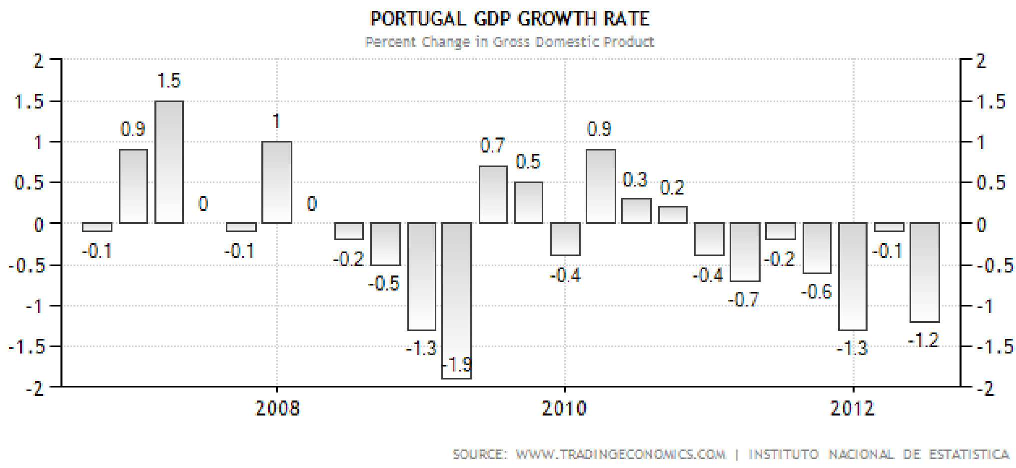

Figure 4.3 – Portugal GDP Growth Rate
Source: www.tradeingeconomics.com/ instituto nacional estatistica. Available at: (http://www.tradingeconomics.com/charts/portugal-gdp-growth.png?s=ptgdpqoq)

Portugal's natural resources are: fish, cork, copper, gold, silver, marble, clay, salt and hydropower**.** Thus its major exports are: agricultural and food products, wine, hides, leather, cork, clothing, footwear. Portugal's major imports are: agricultural and chemical products, vehicles, oil products, base metals, food products, textile materials. It is important to have low tariffs on textiles and apparels in order to support the textile industry (CenterforGlobalDevelopment, 2012b).

With Portugal's existing economic crisis, Tecnodeck is a great welcome to the market as it has seen its market share grow as well as its popularity. In an economic situation of cutting costs and expenses, Tecnodeck which can be considered a high-end item has enjoyed success and become a trendy product.

Social ("Sociedade da Informação e do Conhecimento - Inquérito à Utilização de Tecnologias da Informação e da Comunicação nas Famílias, 2011,"):

- Population: 10.8 million;
- Unemployment rate: 15 %;
- Literacy rate: 93.3% (total population);
- Population growth rate: 0.181%;
- Ethnicity: African and eastern European immigrants;
- Birth rate: 9.76 births/ 1000 people;
- Internet users: 5.5 million (2011);
- Access to a computer: 68% of households (in 2011 by INE);

- Social values: family is important, mainly in the north and south regions.

Technological

Portugal is in the frontline of technology due to policies that support innovation at home and dissemination of technological advances abroad. Portugal has a wide variety of network transportation: 65 airports, four major ports along the West Coast (important for the Atlantic Ocean traffic routes), 3 319 km of roadways and 82 900 km of railways. Portugal has also been steadily investing in renewable energy and it has one of the biggest solar panel sites of Europe located in *Alentejo*; as well as numerous dams across the country.

Portugal has developed several new technologies and has also applied for many patents. Among its most notable creations are:

- MBNet – internet banking service that allows the user to make transactions and procedures at home;
- *Multibanco* – cash withdrawal machines linked across the country and available for most banks;
- Via Verde – automatic toll payment method through a device installed on the front window of the car.

Market perspectives

Tecnodeck's rivals in Portugal are: Sagidec, Cdeck, Dunik and Timbertech. According to the management, Tecnodeck's market share in Portugal is 60% and it is the currently leader of the WPC industry. Tecnodeck will strive to maintain its position by employing a differentiation strategy.

Belgium

Political-Legal

Belgium belongs to the European Union and as such is subject to its policy, which doesn't allow trade barriers between members. It is a federal parliamentary democracy under a constitutional monarchy and Belgium is divided into three regions: Brussels-capital region, Flemish region (Flanders) and the Walloon region (Wallonia). Belgium's civil law is based on the French civil code although its law has been modified to be in accordance with the legislative norms mandated by the European Union (Indexmundi, 2012).

Economical

Belgium had a GDP of 511.5 billion dollars in 2012 according to (TradingEconomics, 2012a). By analyzing Figure 4.4 below one can see that it has been steadily growing.

Figure 4.4 – Belgium GDP
Source: www.tradeingeconomics.com/ instituto nacional estatistica. Available at: (http://www.tradingeconomics.com/charts/belgium-gdp.png?s=wgdpbelg)

Belgium is a modern and open economy that has gained from its advantageous geographical location. Creating a very good transportation grid, and establishing an industrial and commercial base. Belgium has to import large quantities of raw materials due to the scarcity of natural resources. It also exports large quantities of products such as cars and pharmaceuticals. Belgium trades mostly with EU countries and the USA, having profited from its close proximity to Germany.

One of Belgium's benefits is that it employs foreign tax credits to prevent double taxation of corporate profits earned abroad ("Belgium : Center for Global Development : Initiatives: Active: Commitment to Development Index: Countries," 2012).

Social ("Belgium : Center for Global Development : Initiatives: Active: Commitment to Development Index: Countries," 2012):

- Population: 10.4 million;
- Unemployment rate: 7.4%;
- Literacy rate: 99% (total population);
- Population growth rate: 0.061%;
- Ethnicity: Fleming and Walloon;
- Birth rate: 10.03 births/ 1000 people;
- Internet users: 8.5 million (2011);
- Social values: family plays central role, with people remaining in their hometown developing close extended family;
- Most of its population is concentrated in the region of Flanders.

Technological

Belgium has a good transportation network that consists of: 43 airports, 3 233km of railways, 120 111 km of paved roadways and has 4 ports; the best known port is in Antwerp that is crucial for shipping lanes. Belgium has invested in R&D, specifically medicine and biochemistry. Belgium has a higher proportion of employees in R&D than the EU average and it has cooperated with Germany in several science projects. Belgium also provides patent exceptions for research purposes ("Belgium : Center for Global Development : Initiatives: Active: Commitment to Development Index: Countries," 2012).

Market perspectives

Tecnodeck has exclusive distribution rights in Belgium and has set up an office in order to better follow the Belgian market and its surrounding markets, which have demonstrated a high maturity level regarding the Tecnodeck product.

China Analysis

China is still in the middle of an industrialization process and has been steadily increasing its expenses on R&D. Its economy has also registered a large increase as a result of its industrialization and globalization process.

China has the largest population on the planet and its ratio of natural resources per person is well below the world's average level. Region development is uneven, with differences between provinces and regions being higher than in other countries. China has a vast resource consumption which has fuelled its economic growth in recent years.

A newfound wealth is displayed by its richer habitants and could be explored by Tecnodeck as an opportunity to introduce itself to major customers in China. Having a manufacturing line in China certainly helps in transportation and inventory costs.

The PEST analyses performed have given initial data on the countries that Tecnodeck has an interest in, providing input of the four aspects of each country. These can serve as a first step for further investigation.

4.2.3. BCG Matrix

Since it was impossible to obtain data regarding market share and market growth of the WPC industry, we have only considered information received from management. The BCG Matrix has been applied to Portugal and we have considered that Tecnodeck has 60% of Portugal's market and is thus the industry's leader. We have also compared it to the totality of the WPC market.

In our opinion the composite deck product can be considered a star, since it requires further investment in order to widen its range of product applications and reach industry maturity. This is shown in Figure 4.5 below.

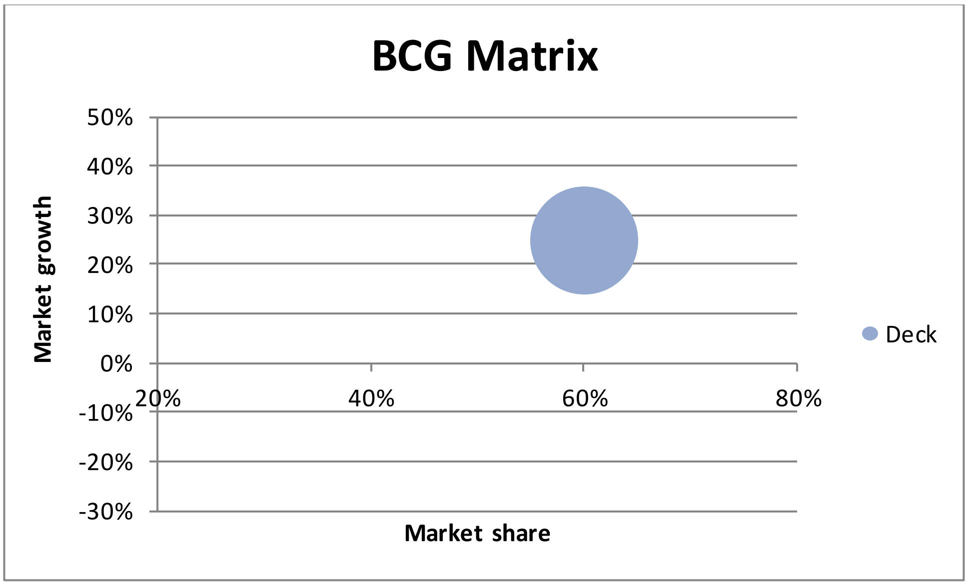

Figure 4.5 – BCG Matrix of Portugal

The BCG matrix has provided data regarding market share and growth, this helps while assessing the environment for competition and what the company can do to maintain its current position in the market.

4.2.4. Porter's Five Forces

In order to complete the industry's environment evaluation we are going to perform a last strategic analysis tool. So we have applied Porter's five forces to the WPC industry according to information Tecnodeck's management provided. Porter's five forces consist of:

1. Industry Rivalry;
2. Suppliers (Supplier Power);
3. Buyers (Buyer Power);
4. Substitutes (Threat of Substitutes);
5. Potential Entrants (Threat of Mobility).

1. Industry Rivalry

The first force to be analysed is the rivalry that exists in the wood plastic composite industry, where Tecnodeck operates.

1. Does Tecnodeck have rivals in the WPC industry? Where and who?

A: Yes it does. There are four rivals in Portugal and others abroad. The rivals in Portugal are: Sagideck, Cdeck, Dunik and Timbertech. Tecnodeck's rivals abroad are: Greenwood in Italy and Deceuninck in Belgium.

2. Top company market share: 60% by Tecnodeck in Portugal, more data regarding international markets is unavailable.

3. Intense rivalry due to globalization and new technologies.

4. According to management there weren't any mergers or acquisitions of existing companies that resulted in new and stronger companies.

2. Suppliers

The second force is supplier power. When suppliers have leverage over their customers and are able to dictate the price of their supplies, as prices may rise because the customer has few alternatives to get his raw materials or products from.

1. Does Tecnodeck have only one supplier of raw materials?
   A: Tecnodeck has two suppliers of WPC shapes and more national suppliers for parts such as aluminum shapes and steel clips, outsourcing these parts.

2. Do Tecnodeck's suppliers have bargaining power?
   A: No, because only Tecnodeck knows the "recipe" for the raw materials and the finishing. Furthermore, it has two suppliers to decrease cost and reduce the risk of supply failing.

3. Are middlemen required?
   A: No, business is done directly with suppliers.

3. Buyers

The third force to be analyzed is buyer power, where buyers have bargaining power. Usually this happens because the customer has several suppliers to choose from and thus is able to drive the price down.

1. What are the usual clients of the Tecnodeck product?
   A: Tecnodeck has several types of buyers, the most important being: hotel chains, architects, landscaping companies and pool construction companies.

2. Who can be a buyer of the Tecnodeck product?

A: Almost every homeowner, mostly those with gardens and pools, hotels, spas, restaurant and cafés that have an outside area and architectures and designers which require very specific products for their projects.

3. What is the market share of the Tecnodeck's buyers?

   A: Accurate percentages of client share aren't available. According to management a small percentage belong to architects, who include the Tecnodeck product in many of their projects that construction companies then use. Larger percentages belong to landscaping and pool business, and hotels.

4. Substitutes

The fourth force concerns substitute products and their corresponding threat. Existing or new products developed by new technologies pose a threat to one's product.

1. Are there substitute products for Tecnodeck?

   A: Yes there are.

2. Are there cheaper substitutes? Which?

   A: Yes, there are tile and wood floors.

3. Are there more expensive substitutes? Which?

   A: Yes, there are exotic woods like Teca or natural stones.

4. Do buyers look for substitutes of Tecnodeck?

   A: They sometimes do, but end up choosing Tecnodeck if they look for long term quality. If they install wood, it may have several maintenance problems at a greater cost.

5. Potential Entrants

The fifth and last force concerns the barriers of entry that new competitors face when they enter the market.

1. Patent and R&D obstacles?

   A: There are none.

2. New regulations? Legal? Environmental?

   A: None.

After the question and answer method that was applied considering Porter's five forces. We now present a summary of Porter's five forces in the WPC industry, shown in Figure 4.6 below:

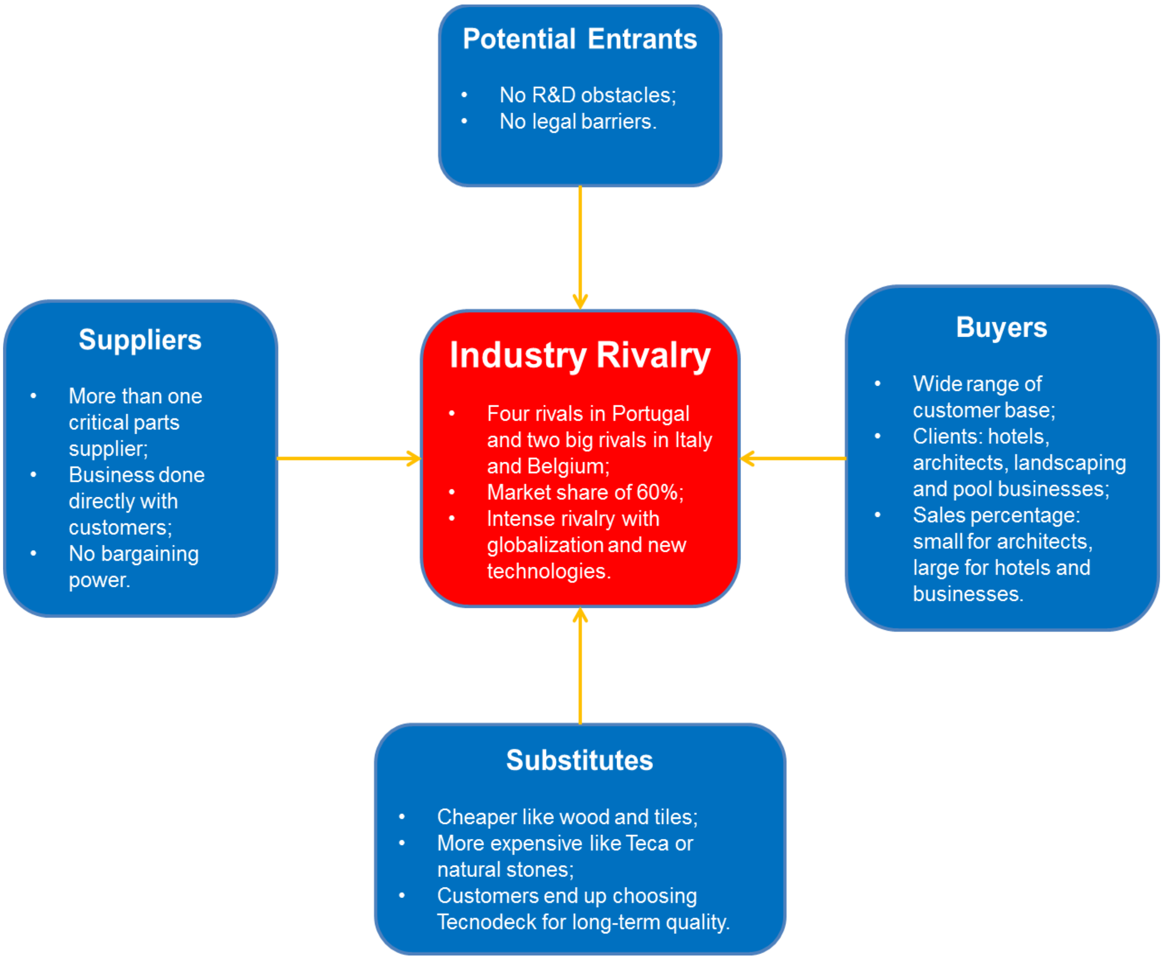

Figure 4.6 – Porter's Five Forces in the WPC industry

This was Porter's five forces analysis summary report and it has revealed a few situations. It has shown that there is intense rivalry in Portugal and abroad with multiple rivals; that supplier and customer power are low; that there are cheaper and more expensive substitute products and that there are no barriers of entry in the WPC industry according to Tecnodeck's management.

This has provided an accurate picture of the situation in the WPC industry environment. Thus one can say that the WPC industry has very welcoming prospects but as management stated many companies have come and gone, which means it may not be so easy to compete in this market as companies might have expected.

4.2.5. Balanced Scorecard Analysis

After executing four strategic analysis tools that assessed the company's environment and industry where it operates, we can now properly create a strategy for the company. The Balanced Scorecard is an important tool when considering the development of a company's strategy, because it provides an analysis of the company's strategy, by aligning goals to long-term targets and budget, and sharing information regarding strategy to personnel.

The Balanced Scorecard shown in Figure 4.7 has been created regarding the Portuguese market and not the international markets, because we have data on the Portuguese market (i.e. market share). Although at a later stage, it would also be interesting to do a BSc for the Italian and the Belgian markets because of Tecnodeck's interests and operations in these countries. As stated before, Tecnodeck has a large market share of the Portuguese market (60%), being the current market leader for the composite deck in the WPC industry.

We have considered a goals and according measures for each of the BSc's perspectives. The purpose of these will be explained further along, as this is the initial analysis.

Learning and Growth Perspective

Goals	Measures
Threats and substitutes	New competing technologies
Improve employee qualifications	Promote leadership capacities at all levels

Internal Process Perspective

Goals	Measures
Flexible response	Number of customizations/ average response time
Efficiency	Improve existing applications

Customer Perspective

Goals	Measures
Customer perception of service	Number of customer interaction points
Customer perception of flexibility	Customer perception of flexible response
Customer satisfaction	Customer feedback

Financial Perspective

Goals	Measures
Cash flow	Money transformation process
Income	Customer growth & profitability
Decrease of unitary costs	% of supply chain goal costs achieved

Figure 4.7 – BSc applied to Portugal

We will now explain in greater detail the measures we suggested for each perspective.

Learning and Growth:

1. Possible threat of new competing technologies, warns the company if new technologies may become a threat to their operations in the future;
2. Promote leadership capacities at all levels, to increase employees' abilities and as professional motivation.

Internal Process perspective:

1. Measures how the company can accommodate customized orders without causing delays, in order to improve processes in the case of the existence of delays of order customization;
2. Efficiency demonstrates the improvement of existing applications.

Customer perspective:

1. Number of customer interaction points measures the service quality, which determines how many people the customer interacts with, in order to be serviced. The larger the number of customer interaction points, the greater the risk of: miscommunication and waste which can result in an increase of delayed responses;
2. Customer's awareness of the relationship between customization and response time. Ability to make customized orders and understanding if these are being provided in the allocated time frame;
3. Customer feedback to improve customer service, processes and to identify and understand new trends. Helps increase customer satisfaction levels and integrate their suggestions, if possible.

Financial perspective:

1. Time spent transforming money spent on raw materials into cash gained from a finished product, so as to understand the amount of time taken to gain profit from a finished product;
2. Measures annual sales and profits of major customers. Sales should increase annually and number of customers should also increase but always with profit. To understand if company is growing correctly or not, i.e. increasing number of customers but with no extra profit;
3. Related to financial goal costs achieved. Goals that actually result in cost reductions and not just in a decrease of time or capacity.

The BSc is a precious tool for management and customers when implementing a strategy, as it defines and communicates a strategy. We have defined the measures and their corresponding goals and now we will try to link them. The purpose of creating a strategy map is to have a set of performance indicators that will help users understand the created strategy.

In order to suggest a strategy we must first analyse the existing strategy. Tecnodeck's existing strategy consists in the development of new product applications (innovation) and the improvement of its processes; these two guidelines of innovation and improvement resemble a basic differentiation strategy. Because Tecnodeck has had such a great success with its existing strategy in the Portuguese market, we suggest that it should continue with this strategy but with some adjustments. Adjustments such as promoting leadership across the organization, number of customizations/average response time, customer perception of flexible response and customer growth and profitability among others. Some of the adjustments are related to the previously applied strategic analysis tools, for example:

- New competing technologies – it is easy for companies to enter the WPC industry with new technologies as Porter's Five Forces state that there are no R&D or legal barriers;
- Customer feedback – the BCG Matrix shows Tecnodeck's market positioning and in order for the company to maintain this positioning, it is vital that the company understands what characteristics the customer values most;
- Number of customizations/average response time – in the PEST analysis of Portugal, other rivals are presented and if Tecnodeck wants to keep rivals at bay than this measure is very important because it can affect the client's perception of the company;
- Customer growth and profitability – in the SWOT analysis, a weakness is identified as competitive market. Because Tecnodeck is operating in such a market than it is suggested that Tecnodeck should analyse its clients' financial health in order to develop partnerships with continuously successful companies.

These are a few relationships of several that could be stated.

After presenting goals and measures, we have created a map that demonstrates the links between measures of the four perspectives of the BSc (albeit considering the links are not always precise). Thus, we suggest below the strategy Tecnodeck should adopt when applied to the Portuguese market:

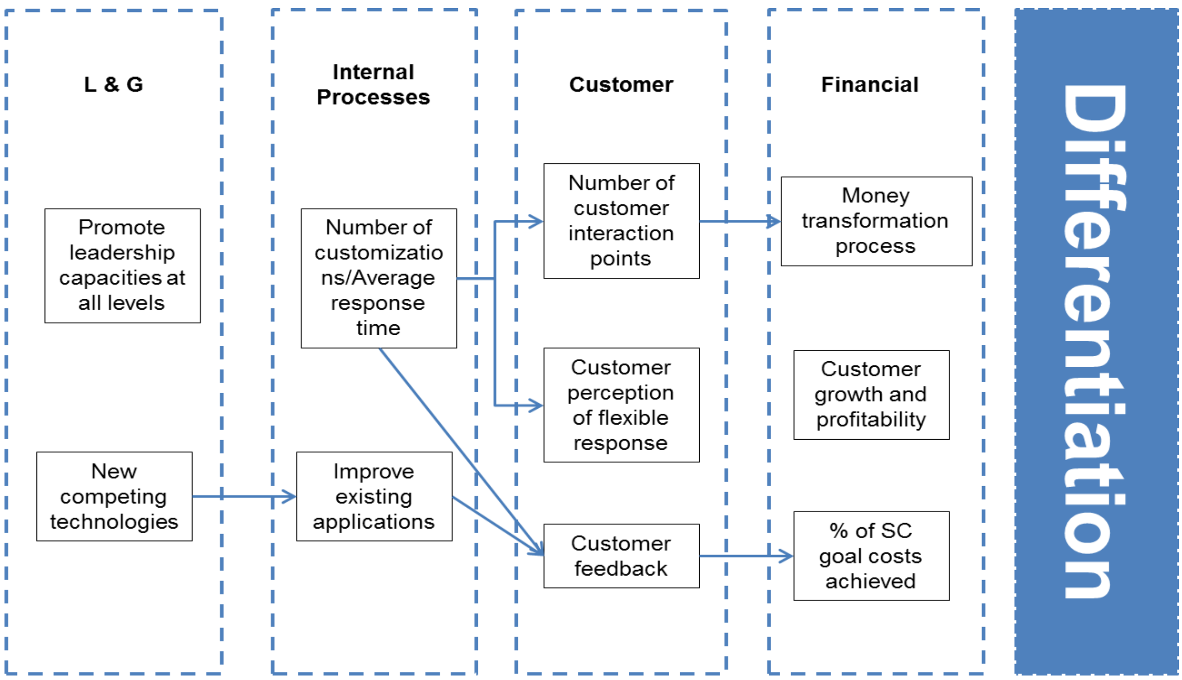

Figure 4.8 – Strategic Map of BSc applied to Portugal

As shown in Figure 4.8 the suggested strategy for Portugal is a basic differentiation strategy. By continuing to improve its processes and widening its range of applications, coupled with the included adjustments (stated in the previous paragraph) we hope that Tecnodeck can consolidate its position as market leader, further establish its brand image and create a bigger gap in client perception between its product and its rivals'. We now explain some of the causal links between perspectives:

- New competing technologies (L&G) and improve existing applications (Int. Proc.) – by identifying and being forewarned of possible threats of new technologies, the company is able to improve its existing product applications accordingly in order to decrease the influence of a new technology appearing in the composite deck market;
- Number of customizations/average response time (Int. Proc.) and Customer measures – by knowing the extent to which the company can take on customized orders without causing delays in orders, the company is able to optimize the number of customer interaction points, to improve ability to accommodate specifications of customized orders and their corresponding lead time;
- Improve existing applications (Int. Proc.) and Customer feedback (Customer) – by improving applications we hope to increase customer satisfaction with new products;
- Number of customer interaction points (Customer) and Money transformation process (Financial) – by optimizing the number of interaction points we hope to decrease the time it takes to transform money spent on raw materials into a finished product;
- Customer feedback (Customer) and % of SC goal costs achieved (Financial) – by having customer feedback on products and/ or service, we can identify and adjust the financial goal costs that were set. This helps the company greatly in cost reduction by knowing what the customer values and thus adjusting the goals accordingly.

It is useful to explain the links created between measures in order to develop the strategy. Although there are several strategies one can employ with these measures, we remain convinced that the basic differentiation strategy is the best suited for the Portuguese market.

We considering it interesting to analyze that one of the results of adopting a basic differentiation strategy is the opportunity for the company to apply a premium or higher price to its products; this can be in agreement with the client's perception of Tecnodeck's product as a luxury item. By being more expensive the product could further establish its identity as a luxury item and thus ensure its growing popularity.

With this tool we are able to assess and develop a strategy for the company (differentiation), based on information retrieved from the four previous strategic analysis tools regarding the industry's environment. Only after the environment is properly defined and evaluated, can we begin to study the company and its strategy.

The strategy suggested in this chapter is independent from the strategy suggested for Portugal in sub-chapter 4.7 – Strategy formulation, because the strategy suggested in sub-chapter 4.7 is based on a different source of data (surveys' results).

All strategic tools applied were based on research and interviews with management and not on the survey's results. They are independent from the analysis performed on sub-chapter 4.4.

4.3. Lean Performance Measures

After completing the application of the strategic analysis tools for Tecnodeck, we are going to begin a new analysis. The new analysis's purpose is to realize the objective of this dissertation, which is the identification of lean performance measures. After identifying the lean performance measures, we will be able to create a survey with these measures and obtain valuable results where the importance of each performance measure is given by each user. The results will be discussed in order to arrive at the conclusions for the best application of the lean philosophy in the WPC industry.

After collecting lean performance measures through a revision of scientific literature (sub-chapter 2.6), we grouped the same measures from five different authors in Table 4.2:

Table 4.2 – Performance measures table with corresponding authors

	Performance Measures	**Authors**	**Notes**
1	Setup time (R)	[2], [3], [5]	
2	Warranty costs (Cost of repair after installation)	[1], [3]	
3	Lead time of customer's orders	[1], [3], [4], [5]	Possible confusion between items: customer delivery lead time[1]; customer lead time[3]; Lead time of customers' orders[4]; Order lead time[5]
4	Supplier delivery lead time	[1], [3]	Possible confusion between items: supplier delivery lead time[1], supplier or delivery lead time[3]
5	Rework	[1], [5]	Adaptation of item: percentage of reworks [1]
6	Percentage of unscheduled downtime	[3], [4], [5]	Possible confusion between items: % of unscheduled downtime[3], % of time machines are standing due to malfunction[4], machine downtime[5]
7	Percentage of defective parts adjusted by production line workers (R)	[3], [4]	Item removed after filtering
8	Value added-time	[1], [3]	Adaptation of item: Percentage of value-added time
9	Batch size	[3], [4], [5]	Possible confusion between items: production and delivery lot sizes[4] , lot sizes (average for each production) [5]
10	Percentage of production equipment that is computer integrated or automated (R)	[3], [4]	
11	WIP inventory	[3], [5]	

12	Percentage of manufacturing processes under statistical control	[2], [3]	
13	Implemented suggestions	[4], [5]	Adaptation of item: Percentage of implemented suggestions
14	Percentage of inspections carried out by autonomous defect control (R)	[3], [4], [5]	Possible confusion between items: Autonomous control (% of quality inspection done by the team) [5]
15	Number of suggestions made to suppliers	[3], [4]	
16	Percentage of procedures which are written or documented in the company	[3], [4], [5]	
17	Number of suggestions per employee per year	[3], [4], [5]	
18	Average number of suppliers for the most critical parts	[3], [4]	
19	Level of integration between supplier's delivery and the company's production information systems (R)	[3], [4]	
20	Percentage of parts co-designed with suppliers	[3], [4]	
21	Frequency of preventive maintenance	[3]	
22	Percentage of preventive maintenance over total maintenance	[3], [4]	
23	Percentage of employees working in teams (R)	[3], [4]	
24	Number of teams	[3]	
25	Percentage of employees cross trained to perform three or more jobs (R)	[3], [5]	Item removed after filtering
26	Percentage of employees rotating tasks (R)	[4]	
27	Number of employees capable of assignment rotation	[5]	
28	Manufacturing cost per unit	[1], [3],	
29	Manufacturer product-mix flexibility	[1], [3]	Possible confusion between items: number of mixed models in a line[3]
30	Supplier volume flexibility	[1]	
31	Existence of supplier certification program	[2], [3]	Possible confusion between items: number of certified suppliers[3]
32	On-time delivery	[3]	Adaptation of item: Percentage of on-time delivery
33	On-time delivery to customers	[1]	
34	Value of WIP relative to sales	[3], [4]	
35	Inventory rotation	[4]	
36	Number of inventory rotations	[3]	
37	Percentage of standardized processes	[1]	
38	Repair costs	[3]	Adaptation of item: scrap and rework costs
39	Value of scrap and rework relative to sales	[4]	

40	Pulling processes	[2], [5]	Possible confusion between items: Production is "pulled by shipment of finished products/ Production at stations "pulled" by the existing demand of the succeeding station/ Usage of "pull" production system[5]
41	Percentage of parts delivered JIT by suppliers (R)	[4]	Item removed after filtering
42	Key suppliers deliver to the plant on JIT basis (R)	[2]	Item removed after filtering
43	We try to form long term relationships with suppliers	[2]	
44	Average length of contract with critical suppliers	[4]	
45	Increased flexibility	[3]	
46	Percentage of parts delivered JIT between sections in the production line (R)	[3], [4]	Item removed after filtering
47	Percentage of common or standardized parts	[3, [4]	
48	Frequency that information is given to employees	[4], [5]	
49	Order flow time (time spent by an order in the shop floor)	[5]	
50	Production capacity	[3]	
51	Container size	[3]	

Codes given to Authors:
[1] – Behrouzi & Wong, 2011 (Behrouzi & Wong, 2011)
[2] – Shah & Ward, 2007 (Shah & Ward, 2007)
[3] – Gurumurthy & Kodali, 2009 (Gurumurthy & Kodali, 2009)
[4] – Sánchez & Pérez, 2001 (Sánchez & Pérez, 2001)
[5] – Duque & Cadavid, 2007 (Manotas Duque & Rivera Cadavid, 2007)

We then proceeded to filter the performance measures from Table 4.2 according to the most commonly found on the reviewed literature. Secondly we applied another filter, replacing a few of lean's performance measures related to manufacturing. Finally we decided to group the performance measures into four categories: cost, time, flexibility and quality.

These four categories have also been researched by Schonsleben and Sheperd and Gunter (2004 *apud* Gopal & Jitesh, 2012) when regarding supply chain performance measures. The categories constitute a preliminary approach to supply chain measures and therefore we have considered that it is important to assign each performance measure to one of the four categories. This has been performed in order to facilitate the users' comprehension of the survey and to have a broader overview of each set of performance measures, when considering the importance that users attribute to the performance measures. The result of this selection and categorization is presented in Table 4.3:

Table 4.3 – Performance Measure Categorization

Performance Measure Categorization	
Quality	**Flexibility**
5) Percentage of reworks; 13) Percentage of implemented suggestions; 15) Number of suggestions made to suppliers; 17) Number of suggestion per employee per year; 38) Frequency that information is given to employees. **REMOVED:** 7) Percentage of defective parts adjusted by production line workers; 10) Percentage of production equipment that is computer integrated or automated; 14) Percentage of inspection carried out by autonomous defect control; 19) Level of integration between suppliers' delivery and the company's production information systems.	9) Batch size; 18) Average number of suppliers for most critical parts; 30) Supplier volume flexibility; 35) Inventory rotation; 45) Increased flexibility; 47) Percentage of common or standardized parts; 50) Production capacity; 51) Container size. **REMOVED:** 23) Percentage of employees working in teams; 25) Percentage of employees cross-trained to perform three or more jobs; 26) Percentage of employees rotating tasks; 46) Percentage of parts delivered JIT between sections in the production line.
Cost	**Time**
2) Warranty costs (cost of repair after installation); 9) Batch size (average); 28) Manufacturing cost per unit; 34) Value of WIP relative to sales; 37) Percentage of common or standardized parts; 38) Repair costs; 50) Production capacity; 51) Container size.	3) Lead time of customer's orders; 4) Supplier delivery lead time; 8) Value-added time; 32) On-time delivery to customers; 49) Order flow time (time spent by an order in the shop floor). **REMOVED:** 1) Setup time; 6) Percentage of unscheduled downtime.

As mentioned before we had to take into account that the manufacturing line is outside of Portugal. Therefore, we had to replace a few of the performance measures that were directly related to manufacturing. The replaced items have been marked in Table 4.2 with the code (R) and on the note column they are indicated as "item is removed after filtering". In Table 4.3 the removed items have a list of their own in their according category, these items were removed in order to facilitate user comprehension.

After filtering the lean performance measures we decided to add a fifth category, Critical Activities. With the help of Tecnodeck's staff, we identified three critical activities which belong to the final assembly process. These are:

1. Exterior supports' fixation;
2. Distancing between supports;
3. Distance between boards.

The purpose of adding the Critical Activities' category is to have a category that by itself is representative of lean's component (added-value) and also because it is a category where users can compare the three activities and thus better inform the company of possible corrective actions and/or preference.

We then grouped the five categories and created a survey, according to the *Likert* scale (1 to 5), which was delivered to Tecnodeck's staff. The users were asked to quantify each lean performance measure according to their judgment and if possible offer suggestions. The survey is presented in the annex, designated Annex III.

4.4. Survey Results

After completing the identification of the lean performance measures, we have to treat the results obtained from the surveys in order to form conclusions.

Eleven results were obtained and can constitute a small sized sample, but no more results were possible because of the company's size. Thus the surveys' results indicate that there were 11 employees from the Tecnodeck staff, which included: Technical Manager, Financial Manager and Budgeting among those who wrote their job occupation. This confirms the company's small size. The suggestion box at the end of the survey was found empty, no users offered suggestions.

The survey has been created in Portuguese for the staff's easier comprehension. Table 4.4 helps readers identify which performance measure is measured in each question and attributes a code accordingly.

Table 4.4 – Questions, Performance measures and Codes

Questions (items)	Performance Indicator	Code
Quality		
Question 1	Rework	Q1
Question 2	Employees suggestions	Q2
Question 3	Implemented suggestions	Q3
Question 4	Suggestions made to suppliers	Q4
Question 5	Management sharing information with employees	Q5
Flexibility		
Question 1	Batch size	F1
Question 2	Increased flexibility	F2
Question 3	Production capacity	F3
Question 4	Container size	F4
Question 5	Critical parts suppliers	F5
Question 6	Supplier volume flexibility	F6

Question 7	Inventory rotation	F7
Question 8	Standardized or common parts	F8
Cost		
Question 1	Warranty costs (after installation)	C1
Question 2	Batch size	C2
Question 3	Production capacity	C3
Question 4	Container size	C4
Question 5	Reduction of manufacturing cost per unit	C5
Question 6	WIP relative to sales	C6
Question 7	Reduction of repair cost (before sale)	C7
Question 8	Standardized or common parts	C8
Time		
Question 1	Client lead-time	T1
Question 2	Supplier lead-time	T2
Question 3	Delivery on time to the client	T3
Question 4	Order flow time in higher demand season	T4
Question 5	Order flow time in smaller demand season	T5
Question 6	% of time creating value in higher demand season	T6
Question 7	% of time creating value in smaller demand season	T7
Critical Activities		
Question 1	Exterior supports fixation	CA1.1
Question 2	Distancing between supports	CA1.2
Question 3	Distance between boards	CA1.3

Two of Time's items from Table 4.3 have been divided to consider high and small demand seasons, thereby creating four items. According to management there is a significant shift in the amount of orders received and work done at Tecnodeck between seasons that justified its inclusion in the survey.

Table 4.4 is useful not only to quickly associate each performance measure to its corresponding question in the survey but also as an overview of the performance measures selected by users.

We have created demographic graphs that give a picture of the user's profile. This is seen in Figure 4.9 and Figure 4.10.

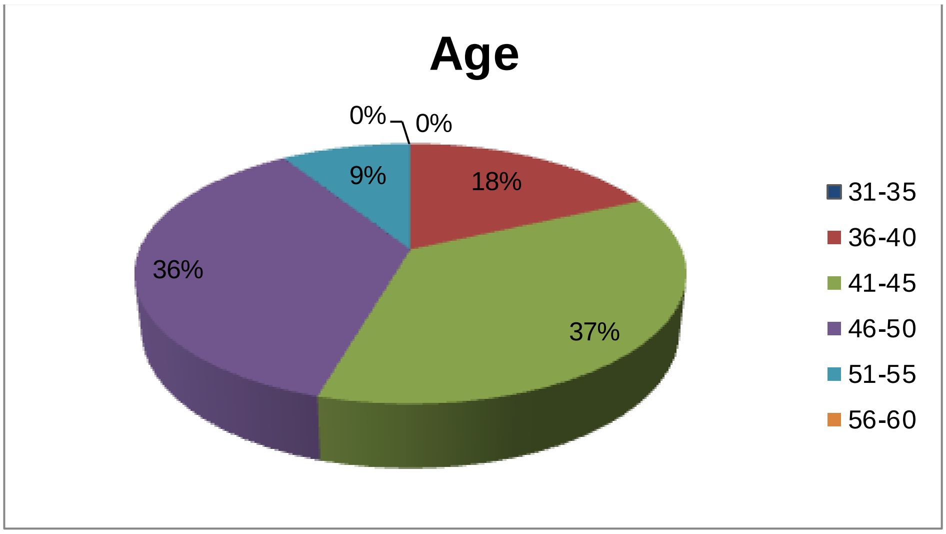

Figure 4.9 – Users' Age

Observing Figure 4.9 we gather that more than two thirds of users belong to the 41-45 and 46-50 age groups, 18% belong to the 36-40 group and 9% belong to the 51-55 group. This shows that the company has only middle-aged personnel. This has to come into evaluation when considering long-term prospects.

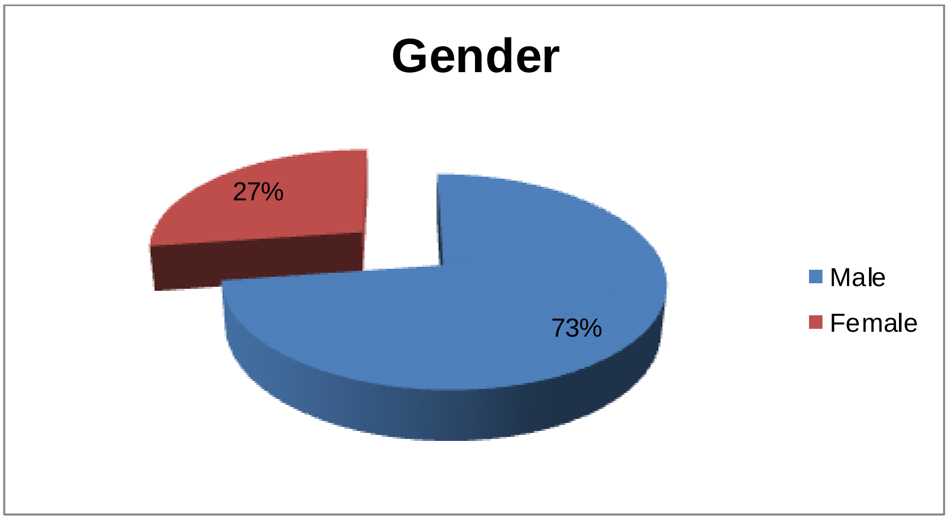

Figure 4.10 – Users' Gender

Observing Figure 4.10 we gather that almost three quarters of users belong to the male category and females comprise the rest of the workforce.

4.4.1. Survey Results Commentaries

Before treating the results with the statistical software, we are commenting on the results obtained with the help of simple statistical math. Table 4.10 presents means, standard deviations, confidence intervals and lower and upper bounds for all items.

Table 4.5 – Mean, Standard deviation, Lower and Upper bounds

Quality	Quality Scores											Mean	Rounded mean	Standard Deviation	Confidence Interval	Lower Bound (LB)	Upper Bound (UB)
1) Rew ork	1	4	2	4	1	2	5	5	3	3	4	3.09	3.1	1.45	0.85	2.24	3.95
2) Employees suggestions	5	5	4	5	5	5	5	5	5	5	5	4.91	4.9	0.30	0.18	4.73	5.09
3) Implemented suggestions	5	4	4	5	4	5	5	3	4	4	3	4.18	4.2	0.75	0.44	3.74	4.63
4) Suggestions made to suppliers	5	4	5	4	4	5	4	3	4	4	4	4.18	4.2	0.60	0.36	3.83	4.54
5) Management sharing information w ith employees	5	5	5	4	4	4	5	4	4	5	4	4.45	4.5	0.52	0.31	4.15	4.76
Flexibility	**Flexibility Scores**																
1) Batch size	3	4	4	3	3	4	3	4	3	2	5	3.45	3.5	0.82	0.48	2.97	3.94
2) Increased flexibility	5	3	4	3	4	4	5	4	4	4	4	4.00	4	0.63	0.37	3.63	4.37
3) Production capacity	5	5	5	5	4	5	5	4	4	5	4	4.64	4.6	0.50	0.30	4.34	4.93
4) Container size	5	5	4	4	4	5	5	3	3	5	4	4.27	4.3	0.79	0.46	3.81	4.74
5) Critical parts suppliers	5	5	5	5	5	5	5	3	4	4	3	4.45	4.5	0.82	0.48	3.97	4.94
6) Supplier volume flexibility	5	5	5	4	4	4	4	4	4	5	4	4.36	4.4	0.50	0.30	4.07	4.66
7) Inventory rotation	5	4	4	5	5	5	5	4	5	4	4	4.55	4.5	0.52	0.31	4.24	4.85
8) Standardized or common parts	5	5	5	5	5	5	5	3	4	4	3	4.45	4.5	0.82	0.48	3.97	4.94
Cost	**Cost Scores**																
1) Warranty costs (after installation)	5	5	5	5	5	5	5	4	4	5	4	4.73	4.7	0.47	0.28	4.45	5.00
2) Batch size	5	4	4	5	5	5	4	3	3	5	3	4.18	4.2	0.87	0.52	3.67	4.70
3) Production capacity	5	4	5	5	5	4	4	4	4	5	3	4.36	4.4	0.67	0.40	3.97	4.76
4) Container size	5	5	5	5	5	5	5	3	5	3	3	4.45	4.5	0.93	0.55	3.90	5.01
5) Reduction of manufacturing/production cost per unit	5	5	5	5	5	5	5	3	4	5	4	4.64	4.6	0.67	0.40	4.24	5.03
6) WIP relative to sales	2	5	2	2	3	2	5	3	2	2	3	2.82	2.8	1.17	0.69	2.13	3.51
7) Reduction of repair cost (before sale)	1	3	2	1	2	2	5	4	3	3	3	2.64	2.6	1.21	0.71	1.92	3.35
8) Standardized or common parts	5	4	5	5	5	5	5	4	4	4	4	4.55	4.5	0.52	0.31	4.24	4.85
Time	**Time Scores**																
1) Client lead-time	5	5	5	5	5	5	5	4	4	4	5	4.73	4.7	0.47	0.28	4.45	5.00
2) Supplier lead-time	5	5	5	5	5	5	5	4	4	4	4	4.64	4.6	0.50	0.30	4.34	4.93
3) Delivery on time to the client	5	5	5	5	5	5	5	5	5	5	4	4.91	4.9	0.30	0.18	4.73	5.09
4) Order flow time, in higher demand season	51 - 75%	0 - 25%	51 - 75%	51 - 75%	26 - 50%	51 - 75%	0 - 25%	0 - 25%	51 - 75%	51 - 75%	51 - 75%	-	-	-	-	-	-
5) Order flow time, in smaller demand season	76 - 100%	0 - 25%	76 - 100%	76 - 100%	76 - 100%	76 - 100%	26 - 50%	0 - 25%	76 - 100%	76 - 100%	76 - 100%	-	-	-	-	-	-
6) % of time creating value, in higher demand season	51 - 75%	0 - 25%	51 - 75%	51 - 75%	76 - 100%	51 - 75%	26 - 50%	0 - 25%	51 - 75%	51 - 75%	76 - 100%	-	-	-	-	-	-
7) % of time creating value, in smaller demand season	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	-	-	-	-	-	-
Critical Activities	**Critical Activities Scores**																
1.1) External supports fixation	5	5	5	5	4	5	5	3	5	3	5	4.55	4.5	0.82	0.48	4.06	5.03
1.2) Distancing betw een supports	5	5	5	4	5	4	5	3	3	5	3	4.27	4.3	0.90	0.53	3.74	4.81
1.3) Distance betw een boards	5	5	4	4	4	4	5	3	3	3	4	4.00	4	0.77	0.46	3.54	4.46

Table 4.5 is a good resource to detect abnormal results with the help of the lower and upper bounds.

After reviewing the results and considering Table 4.5, we have created Table 4.6 which has short commentaries regarding each item. Values are marked with yellow to show they are out of the calculated bounds, and red to show they are abnormal results in the Time category.

Table 4.6 – Items, Item's values, Means, Lower and Upper bounds and Commentaries

Quality	Quality Scores											Mean	Lower Bound (LB)	Upper Bound (UB)	Commentaries
1) Rework	1	4	2	4	1	2	5	5	3	3	4	3.09	2.24	3.95	Values below LB and above UB
2) Employees suggestions	5	5	4	5	5	5	5	5	5	5	5	4.91	4.73	5.09	Values below LB
3) Implemented suggestions	5	4	4	5	4	5	5	3	4	4	3	4.18	3.74	4.63	Values below LB and above UB
4) Suggestions made to suppliers	5	4	5	4	4	5	4	3	4	4	4	4.18	3.83	4.54	Values below LB and above UB
5) Management sharing information with employees	5	5	5	4	4	4	5	4	4	5	4	4.45	4.15	4.76	Values below LB and above UB
Flexibility	**Flexibility Scores**														
1) Batch size	3	4	4	3	3	4	3	4	3	2	5	3.45	2.97	3.94	Values below LB and above UB
2) Increased flexibility	5	3	4	3	4	4	5	4	4	4	4	4.00	3.63	4.37	Values below LB and above UB
3) Production capacity	5	5	5	5	4	5	5	4	4	5	4	4.64	4.34	4.93	Values below LB and above UB
4) Container size	5	5	4	4	4	5	5	3	3	5	4	4.27	3.81	4.74	Values below LB and above UB
5) Critical parts suppliers	5	5	5	5	5	5	5	3	4	4	3	4.45	3.97	4.94	Values below LB and above UB
6) Supplier volume flexibility	5	5	5	4	4	4	4	4	4	5	4	4.36	4.07	4.66	Values below LB and above UB
7) Inventory rotation	5	4	4	5	5	5	5	4	5	4	4	4.55	4.24	4.85	Values below LB and above UB
8) Standardized or common parts	5	5	5	5	5	5	5	3	4	4	3	4.45	3.97	4.94	Values below LB and above UB
Cost	**Cost Scores**														
1) Warranty costs (after installation)	5	5	5	5	5	5	5	4	4	5	4	4.73	4.45	5.00	Values below LB
2) Batch size	5	4	4	5	5	5	4	3	3	5	3	4.18	3.67	4.70	Values below LB and above UB
3) Production capacity	5	4	5	5	5	4	4	4	4	5	3	4.36	3.97	4.76	Values below LB and above UB
4) Container size	5	5	5	5	5	5	5	3	5	3	3	4.45	3.90	5.01	Values below LB
5) Reduction of manufacturing/production cost per unit	5	5	5	5	5	5	5	3	4	5	4	4.64	4.24	5.03	Values below LB
6) WIP relative to sales	2	5	2	2	3	2	5	3	2	2	3	2.82	2.13	3.51	Values below LB and above UB
7) Reduction of repair cost (before sale)	1	3	2	1	2	2	5	4	3	3	3	2.64	1.92	3.35	Values below LB and above UB
8) Standardized or common parts	5	4	5	5	5	5	5	4	4	4	4	4.55	4.24	4.85	Values below LB and above UB
Time	**Time Scores**														
1) Client lead-time	5	5	5	5	5	5	5	4	4	4	5	4.73	4.45	5.00	Values below LB
2) Supplier lead-time	5	5	5	5	5	5	5	4	4	4	4	4.64	4.34	4.93	Values below LB and above UB
3) Delivery on time to the client	5	5	5	5	5	5	5	5	5	5	4	4.91	4.73	5.09	Values below LB
4) Order flow time, in higher demand season	51 - 75%	0 - 25%	51 - 75%	51 - 75%	26 - 50%	51 - 75%	0 - 25%	0 - 25%	51 - 75%	51 - 75%	51 - 75%	-	-	-	0-25% abnormal value
5) Order flow time, in smaller demand season	76 - 100%	0 - 25%	76 - 100%	76 - 100%	76 - 100%	76 - 100%	26 - 50%	0 - 25%	76 - 100%	76 - 100%	76 - 100%	-	-	-	0-25% abnormal value
6) % of time creating value, in higher demand season	51 - 75%	0 - 25%	51 - 75%	51 - 75%	76 - 100%	51 - 75%	26 - 50%	0 - 25%	51 - 75%	51 - 75%	76 - 100%	-	-	-	0-25% abnormal value
7) % of time creating value, in smaller demand season	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	0 - 25%	-	-	-	Expected
Critical Activities	**Critical Activities Scores**														
1.1) External supports fixation	5	5	5	5	4	5	5	3	5	3	5	4.55	4.06	5.03	Values below LB
1.2) Distancing between supports	5	5	5	4	5	4	5	3	3	5	3	4.27	3.74	4.81	Values below LB and above UB
1.3) Distance between boards	5	5	4	4	4	4	5	3	3	3	4	4.00	3.54	4.46	Values below LB and above UB

Table 4.6 presents commentaries for every question (item) but a few results require a special commentary. Some because they haven't received the same statistical treatment, % Time items (Items 4, 5, 6 and 7), while others due to their unexpected scores. These are explained below:

Quality:

- 1st Question (item) **Rework** – Average Score: 3.09; Anomaly score: 1.

  This question is linked to rework, which is an important Lean performance measure. We expected it to have high scores but it didn't, because according to Tecnodeck's personnel input, it is a very uncommon event. We presume that users didn't feel it deserved a higher score, which makes it an excellent opportunity for Lean to be applied.

Flexibility:

- 1st Question (item) **Batch size** – Average Score: 3.45; Anomaly score: 3.

  This question regards batch size, where we expected a higher score. The medium importance attributed to this item can be explained by seasonal demand and large transportation times. These two factors hinder Tecnodeck's ability to change batch sizes.

- 4th Question (item) **Container size** – Average Score: 4.27; Anomaly score: 5.

  This question regards container size. Through follow ups with Tecnodeck, we know that Tecnodeck has the possibility to choose between 20 or 40 feet containers. But always chooses the 40 feet containers purely for financial reasons. As such, the score of 5 found on some surveys was odd as this item should have a lower score according to the financial basis of the container's size decision.

Cost:

- 6th Question (item) **WIP relative to sales** – Average Score: 2.82; Anomaly score: - .

  This question is linked to the value of the product (while work in process) relative to sales. WIP relative to sales should have a low score because it is important that sales not rely upon WIP. The low scores obtained can be explained by users considering that WIP has low value until the product is assembled. This happens because incoming orders are not queued but instead each one is attended to almost immediately. As most of the creation of value is achieved upon final assembly at the client's location, the product's value increases dramatically at the client's location. Thus WIP is low along the supply chain and only high at the client's location.

- 7th Question (item) **Reduction of repair cost (before sale)** – Average Score: 2.64; Anomaly score: 1.

  There are a few scores of 1, this can happen because such a repair is very uncommon and is not seen as a priority. This is an important Lean performance measure and thus it is another opportunity for Lean to be applied.

Time:

The following questions aren't created according to the *Likert* scale and thus haven't been treated statistically like the previous questions. We will now comment on their results:

- 4th Question (item) **Order flow time in higher demand season** – Most selected: 51-75%, Anomaly score: 0-25%.

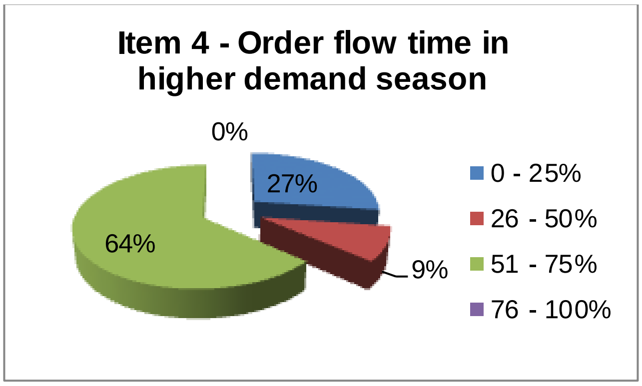

Figure 4.11 – Item 4 Order flow time in higher demand season

This question considers a season with higher demand, where the time the order spends in the shop floor is high and orders move faster because they have to be shipped or assembled at the client's location. Observing Figure 4.11, the most selected option is 51-75% and it could be attributed to user's misinterpretation of the question. The anomaly score of 0-25% is the desired score, as orders and materials should spend less time in the shop floor in a high demand season and more time at the client's location.

- 5th Question (item) **Order flow time in smaller demand season** – Most selected: 76-100%, Anomaly score: 0-25%.

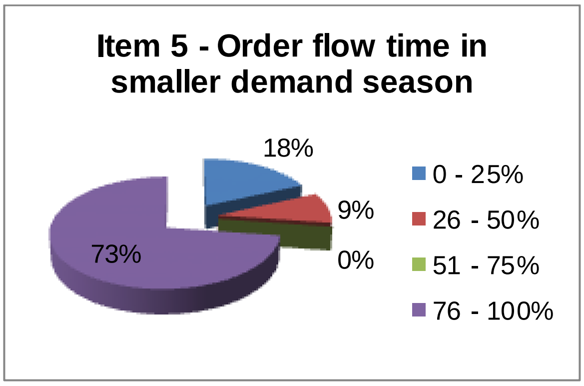

Figure 4.12 – Item 5 Order flow time in smaller demand season

This question considers a season with less demand, where the time the order spends in the shop floor is high but orders move slower because parts are mainly stored and materials lay waiting for the higher demand season. Observing Figure 4.12 the most selected is 76-100% that is the desired score. While an anomaly score of 0-25% could be explained by user misinterpretation of the question, since in the lower demand season it is expected that materials stay longer in storage.

- 6th Question (item) **% of time creating value in higher demand season** – Most selected: 51-75%, Anomaly score: 0-25%.

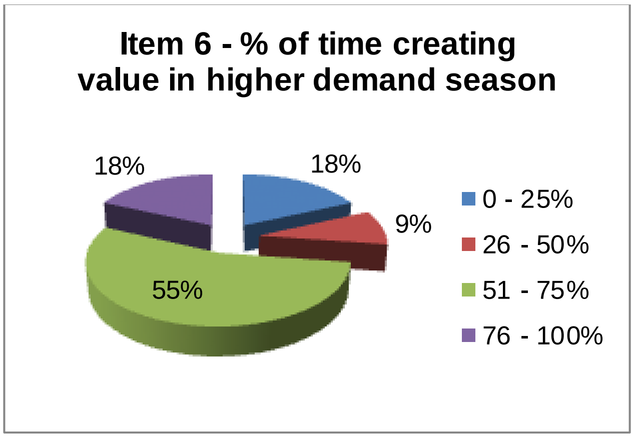

Figure 4.13 – Item 6 Order flow time in higher demand season

This question relates to the percentage of time that value is added to the product in a high demand season. Tecnodeck told us that most of the product is shipped and prepared for final assembly at the client's location, where we know that most of the added value is performed. By observing Figure 4.13 the most selected option is 51-75% that confirms what we said by demonstrating that added-value is mostly performed upon final assembly at the client's location. While an anomaly score of 0-25% could be explained by user misinterpretation of the question, considering the previous explanation that in a higher demand season there is greater adding value time to the product then in a lower demand season.

- 7th Question (item) **% of time creating value in smaller demand season** – Most selected: 0-25%, Anomaly score: - .

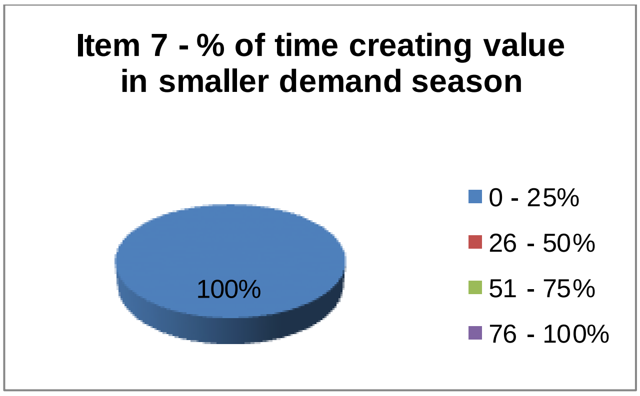

Figure 4.14 – Item 7 Order flow time in smaller demand season

This question relates to the percentage of time that value is added to the product in a lower demand season. Observing Figure 4.14 the most selected option is 0-25%, which is expected because the majority of parts are waiting in storage for the higher demand season, to be shipped or assembled.

Critical activities:

These activities were identified by Tecnodeck's staff as activities that mostly add value to the product and which belong to the final assembly process done at the client's location:

- 1st Question (item) **Exterior support fixation** – Average Score: 4.55; Anomaly score: -.
  This is the first of the identified critical activities; it has received the highest average score and is classified as the most important of the three critical activities;

- 2nd Question (item) **Distancing between supports** – Average Score: 4.27; Anomaly score: -.
  This is the second of the identified critical activities. It has the second highest average score and is classified as the second most important of the three critical activities. Because it received a high score it should be considered an important critical activity as well;

- 3rd Question (item) **Distance between boards** – Average Score: 4.00; Anomaly score: -.
  This is the third of the identified critical activities. It has got the lowest average score, although still significant at 4.00. It is the less important of the three but nonetheless an important critical activity according to users' results.

We had hoped for better results in this section regarding critical activities, where users could judge each critical activity and compare them so that there would be a bigger difference between the three. As it stands, some comparison was obtained and all three critical activities are considered important, which was also expected.

In order to summarize the results above, we created a comparison analysis that provides a clear picture of what the users' input is. This has been applied to the five categories.

Table 4.7 – Summary of % Standardized Mean Sum by Category

Summary of % Standardized Mean Sum by Category				
Quality	**Flexibility**	**Cost**	**Time**	**Critical Activities**
0.833	0.855	0.809	**0.952**	0.855

With the help of Table 4.7 seen above, we are able to create analyses that compared each category: Quality, Flexibility, Cost, Time and Critical Activities. Analyzing Table 4.7, we find that the **Time** category is the most influential as it has the highest score. This is graphically confirmed in Figure 4.15, which has an overall view of the five categories.

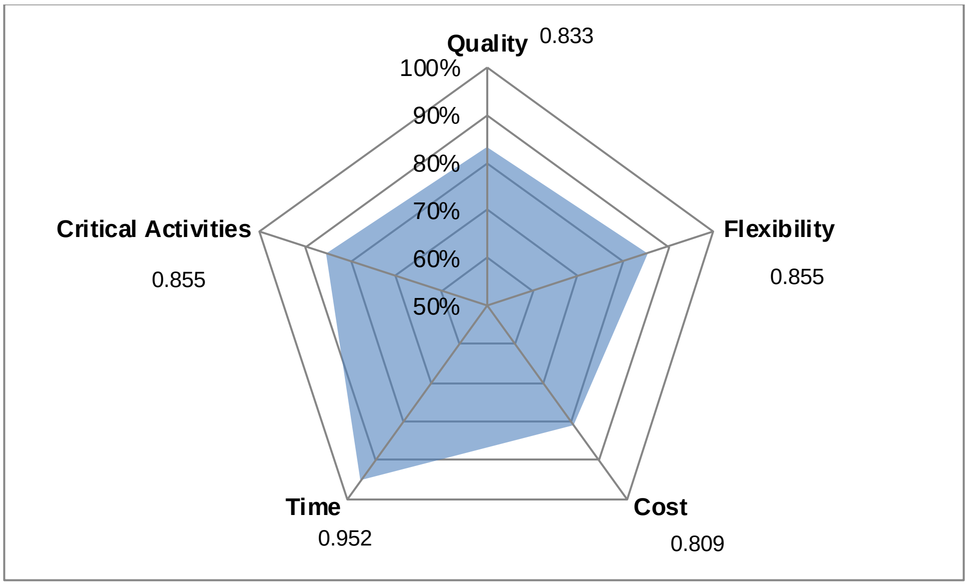

Figure 4.15 – Comparison analysis of Five Categories

Analyzing Figure 4.15 we are able to see that the majority of scores are high. The most important category was **Time** (**0.952**). Secondly, the **Critical Activities** (**0.855**) and **Flexibility** (**0.855**) categories were also rated highly and are considered important. Thirdly is the **Quality** category (**0.833**) and finally **Cost** (**0.809**). In order to identify, assess and understand the importance given to each lean performance measure by users, we performed individual comparison analysis graphics for each category.

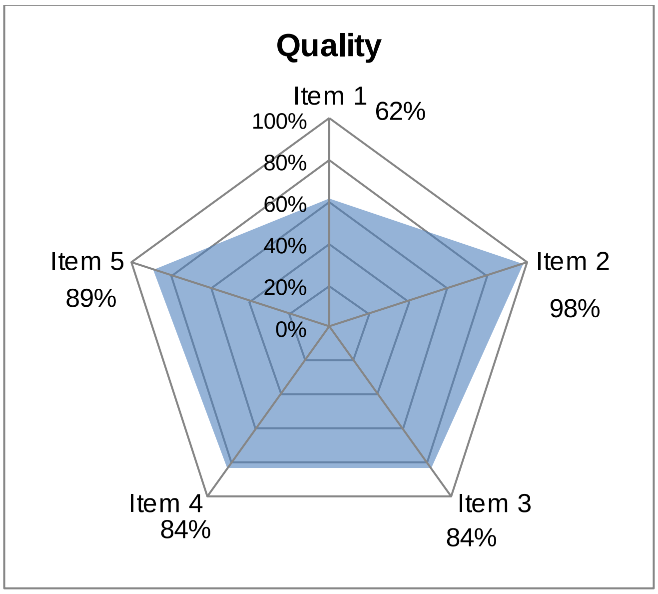

Figure 4.16 – Comparison analysis of Quality items

The first category presented is Quality (shown in Figure 4.16) where Item 2 received the highest score. This item represents **Employee's suggestions** and is followed by Items 5, 3 and 4. These represent: **Management sharing information with employees** (Item 5), **Implemented suggestions** (Item 3) and **Suggestions to suppliers** (Item 4) accordingly. Item 1 **Rework** received the lowest score of the Quality category.

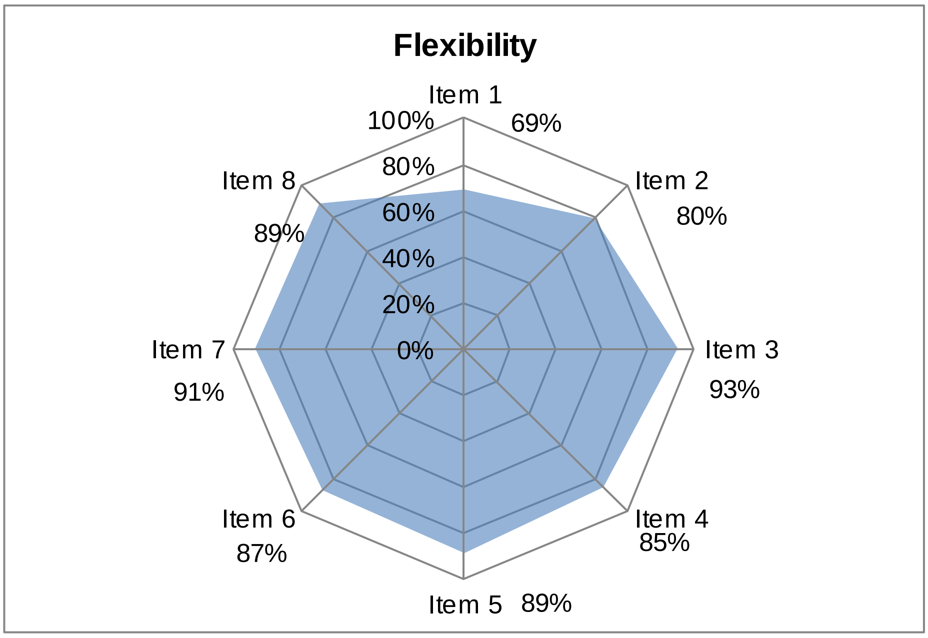

Figure 4.17 – Comparison analysis of Flexibility items

The second category presented is Flexibility (shown in Figure 4.17), where Item 3 received the highest score. This item regards **Production capacity** and although this measure is given a high score, it is difficult to execute. Since Tecnodeck orders in advance, considering seasonal demand and the large distance from its plant in China, it is more difficult to make changes in the production capacity.

The Production capacity item is followed by Items 7, 5 and 8, which represent: **Inventory rotation** (Item 7), **Critical parts Suppliers** (Item 5) and **Standardized or common parts** (Item 8). In turn, they are followed by Items 6, 4 and 2, which represent **Supplier volume flexibility** (Item 6), **Container size** (Item 4) and **Increased flexibility** (Item 2). Finally, Item 1 **Batch size** has the lowest score of the Flexibility category.

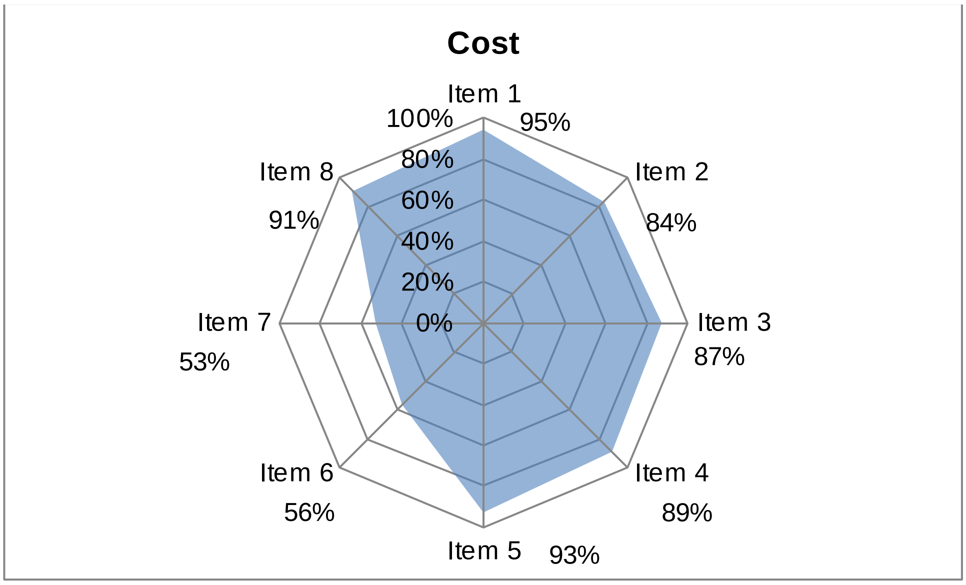

Figure 4.18 – Comparison analysis of Cost items

The third category presented is Cost (shown in Figure 4.18), where Item 1 **Warranty costs (after installation)** received the highest score. This item is followed by Items 5 and 8. These represent**: Reduction of manufacturing unitary cost** (Item 5) and **Standardized or common parts** (Item 8).

Thirdly come items 4, 3 and 2 representing **Container size** (Item 4), **Production capacity** (Item 3) and **Batch size** (Item 2). Finally, items 6 and 7 have received the lowest scores of the Cost category, these represent: **WIP relative to sales** and **Reduction of repair cost (before sale)**.

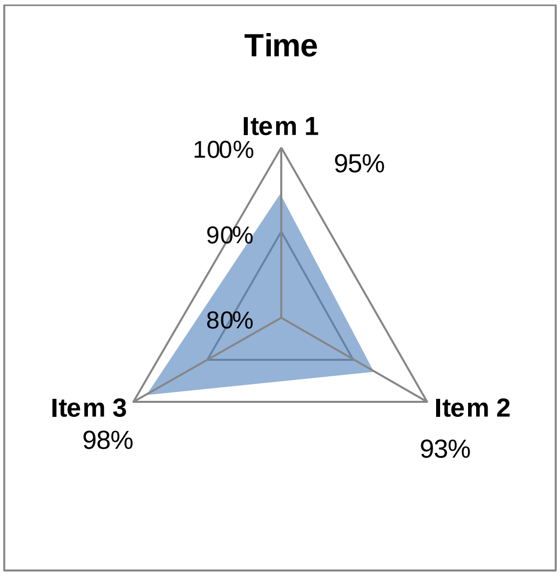

Figure 4.19 – Comparison analysis of Time items

The fourth category presented is Time (shown in Figure 4.19) where Item 3 received the highest score. This item represents **Delivery on time to the client** and is followed closely by

Items 1 and 2. The two items represent: **Client lead-time** (Item 1) and **Supplier lead-time** (Item 2). The other four items of the Time category haven't been included in this analysis since they aren't created according to the *Likert* scale.

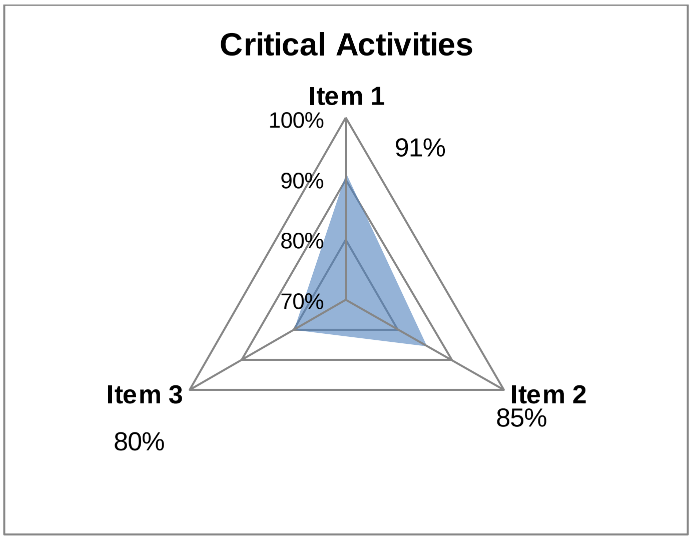

Figure 4.20 – Comparison analysis of Critical Activities items

The fifth and final category presented is Critical Activities (shown in Figure 4.20), where Item 1 received the highest marks. This item represents: **Exterior supports fixation** and it is followed by Item 2 **Distancing between supports**, while Item 3 **Distance between boards** is the last item.

Table 4.8 – Highest and lowest scored items of each Category

Highest and lowest scored item of each Category					
	Quality	Flexibility	Cost	Time	Critical Activities
Highest Score	Q2	F3	C1	T3	CA1.1
Lowest Score	Q1	F1	C7	T2	CA1.3

Observing Table 4.8 we can easily identify the most important and the less important items of each category:

- Considering the Quality category, the most important item for users is **Employees suggestions**(Q2) while the less important is **Rework**(Q1) performed on the product when it arrives;

- In the Flexibility category, the most important item for users is **Production capacity**(F3) while the less important is **Batch size**(F1);
- In the Cost category, the most important item for users is **Warranty costs**(C1) while the less important is **Reduction of repair cost (before sale)**(C7);
- In the Time category, the most important item for users is **Delivery on time to the client**(T3) while the less important is **Supplier lead-time**(T2);
- Finally, in the Critical Activities category the most important item for users is **Exterior supports fixation**(CA1.1) while the less important is **Distance between boards**(CA1.3).

Table 4.9 has a rank of the top 10 items, considering all items of the five categories.

Table 4.9 – Top 10 items

Top 10 items		
Rank	**Items**	**Mean Values**
1	T3	4.91
1	Q2	4.91
3	C1	4.73
3	T1	4.73
5	T2	4.64
5	F3	4.64
5	F5	4.64
10	C8	4.55
10	F7	4.55
10	CA1.1	4.55

Table 4.9 demonstrates what the ten most important items to users are:

- One Quality item;
- Three Flexibility items;
- Two Cost items;
- Three Time items;
- One Critical Activities item.

By analyzing Table 4.9 it is clear that the Flexibility and Time categories are the most important to users. They are closely followed by the Cost category, but it is usual to attribute a high degree of importance to financial items, as are items directly related to it. We now try to explain the influence that finance has on a few items of Time and Flexibility.

Flexibility's items in the top ten (F3, F5 and F7) are somewhat related to financial issues as they are important while saving costs.

- Saving cost through flexible production capacity (Item F3);
- Having more than one supplier of critical parts (Item F5) means that the probability of incurring costs because of shortage of critical parts is lower;
- Inventory rotation, dispatching older items first will help save maintenance costs (Item F7).

Time's items in the top ten (T1, T2 and T3) aren't directly related but contribute perhaps even more than Flexibility's items:

- Lead-times for clients and suppliers can represent great expenses if these are extended. As a result, costs will be incurred and relationships between clients and supplier can be damaged, thereby greatly increasing costs (Items T1 and T2);
- Delivering to the client on time can represent cost savings as clients expect deliveries on time. If these are delayed then potential clients can also be lost (Item T3).

In conclusion, we can state that the **Time** category is the most important due its score of **0.952** and second to it are the **Flexibility** category and **Critical Activities** category, with a score of **0.855** (see Table 4.7). We have considered the **Flexibility** category to be more important than the **Critical Activities** category because it has three items in the **Top 10** table (Table 4.9) instead of Critical Activities' one item in the **Top 10** table. Also all of Flexibility's items in the **Top 10** table have a higher average score than Critical Activities' item. Therefore, **Flexibility** is the second most important category and **Critical Activities** is the third most important category.

Regarding the suggestion box presented at the end of the survey, no suggestions were offered and so none are discussed.

4.4.2. Survey Results Statistical Treatment

Although Tecnodeck is a small company with few employees, the results were sufficient to test statistically for internal consistency reliability and convergent validity. Only four questions, belonging to the Time category (items T4, T5, T6 and T7) aren't treated statistically because they haven't been created according to the *Likert* scale. As such these will not be featured in this sub-chapter.

We are going to test for internal consistency reliability in order to discover the results' reliability, which means how well the items measure their assigned category. And we will test for convergent validity so that we can find out if the items are indeed related to their assigned category (Discriminant validity could be performed to discover if items were not related to their category). The two tests complement each other by confirming that the items are correctly evaluating their category.

4.4.2.1. Internal consistency reliability – Cronbach-alpha coefficient

The first test to be performed is the Cronbach-alpha coefficient, which tests for internal consistency reliability.

Table 4.10 – Cronbach-alpha Coefficient

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.853	0.900	27

Analyzing Table 4.10, one can observe that the Cronbach-alpha coefficient is **0.853**, which is an acceptable score. It belongs to the satisfactory interval as mentioned in the literature review (0.7 – 0.95).

Table 4.11 below demonstrates how the Cronbach-alpha coefficient is affected when one of its items is removed.

Table 4.11 – Alpha if Item Deleted

Item-Total Statistics					
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	**Cronbach's Alpha if Item Deleted**
Quality					
Q1	111.36	95.45	-0.34	.	0.892
Q2	109.55	88.87	-0.16	.	0.857
Q3	110.27	77.42	0.76	.	0.837
Q4	110.27	82.22	0.50	.	0.846
Q5	110.00	82.40	0.57	.	0.845
Flexibility					
F1	111.00	92.20	-0.30	.	0.870
F2	110.45	86.27	0.12	.	0.855
F3	109.82	80.96	0.75	.	0.841
F4	110.18	77.36	0.73	.	0.837
F5	110.00	75.00	0.87	.	0.831
F6	110.09	85.29	0.27	.	0.852
F7	109.91	84.49	0.34	.	0.850
F8	110.00	75.00	0.87	.	0.831
Cost					
C1	109.73	80.82	0.84	.	0.841
C2	110.27	79.22	0.52	.	0.844
C3	110.09	84.29	0.27	.	0.852
C4	110.00	76.40	0.66	.	0.838
C5	109.82	77.96	0.81	.	0.837
C6	111.64	80.85	0.28	.	0.855
C7	111.82	92.56	-0.26	.	0.880
C8	109.91	81.69	0.65	.	0.843
Time					
T1	109.73	82.22	0.67	.	0.844
T2	109.82	79.96	0.87	.	0.839
T3	109.55	85.87	0.38	.	0.851
Critical Activites					
CA1.1	109.91	80.89	0.44	.	0.847
CA1.2	110.18	75.36	0.76	.	0.835
CA1.3	110.45	76.47	0.81	.	0.835

Observing Table 4.11 above, one can identify that the Cronbach-alpha coefficient's score increases when (marked green):

- Item Q1-**Rework** is removed, it increase to 0.892;
- Item F1-**Batch size** is removed, it increases to 0.870;
- Item C7-**Reduction of repair cost** is removed, it increases to 0.880.

If one wants to increase reliability, then these three items should be discarded. Since the coefficient's original result is acceptable, removing these item isn't urgent, because the increase was not significant.

While the Cronbach-alpha coefficient's score decreases when (marked red):

- Item F4-**Container size** is removed, it decreases to 0.837;
- Item F5-**Critical parts suppliers** is removed, it decreases to 0.831;
- Item F8-**Standardized or common parts** is removed, it decreases to 0.831;
- Item C1-**Warranty costs** is removed, it decreases to 0.841;
- Item C4-**Container size** is removed, it decreases to 0.838;
- Item C5-**Reduction of manufacturing cost per unit** is removed, it decreases to 0.837;
- Item CA1.2-**Distancing between supports** is removed, it decreases to 0.835;
- Item CA1.3-**Distance between boards** is removed, it decreases to 0.835.

These eight items are of great importance since, if they are removed, the Cronbach-alpha coefficient decreases. So if one wants to decrease reliability, these items should be removed. But even if we remove one of the mentioned items, the coefficient's score would still be acceptable.

4.4.2.2. Convergent validity – Correlation Matrix

After treating the results for reliability, we are now going to test the results for convergent validity. Although the Pearson correlation test can also be employed, we used the Correlation matrix test because it is more visually appealing and simpler (it doesn't display significance levels) but still produces the results we want.

High positive correlation scores are desired to prove that the items chosen to relate to their assigned category are indeed related to it. While negative correlation scores show that items are related in the opposite manner to the same category. And low correlation scores (near zero value) are considered to indicate that the item has no convergent validity.
Table 4.12 below has the correlation between all items.

Table 4.12 – Correlation matrix of all items

		Q1	Q2	Q3	Q4	Q5	F1	F2	F3	F4	F5	F6	F7	F8	C1	C2	C3	C4	C5	C6	C7	C8	T1	T2	T3	CA1.1	CA1.2	CA1.3	Max value of correlation	Min value of positive correlation	Min value of correlation
Correlation	Q1	1.00	0.25	-0.29	-0.71	-0.06	0.21	-0.22	-0.09	-0.20	-0.46	-0.32	-0.34	-0.46	-0.40	-0.57	-0.55	-0.40	-0.48	0.54	0.71	-0.47	-0.26	-0.36	-0.21	-0.13	-0.40	-0.09	.71	0.21	-.71
	Q2	0.25	1.00	0.08	-0.45	-0.35	-0.22	0.00	-0.24	0.12	-0.22	-0.42	0.35	-0.22	-0.19	0.07	-0.31	-0.19	-0.18	0.23	0.18	-0.29	-0.19	-0.24	-0.10	-0.18	-0.27	0.00	.35	0.07	-.45
	Q3	-0.29	0.08	1.00	0.58	0.28	-0.47	0.21	0.72	0.59	0.83	0.07	0.74	0.83	0.73	0.71	0.45	0.73	0.74	-0.07	-0.36	0.74	0.44	0.72	0.52	0.47	0.51	0.52	.83	0.07	-.47
	Q4	-0.71	-0.45	0.58	1.00	0.35	0.02	0.26	0.57	0.52	0.62	0.42	0.29	0.62	0.55	0.50	0.31	0.55	0.67	-0.37	-0.59	0.61	0.55	0.57	0.10	0.59	0.45	0.43	.67	0.02	-.71
	Q5	-0.06	-0.35	0.28	0.35	1.00	-0.30	0.30	0.69	0.64	0.40	0.83	-0.27	0.40	0.56	0.24	0.34	0.15	0.52	0.31	0.13	0.10	0.15	0.31	0.29	0.06	0.77	0.49	.83	0.06	-.35
	F1	0.21	-0.22	-0.47	0.02	-0.30	1.00	-0.19	-0.29	-0.21	-0.34	-0.20	-0.40	-0.34	-0.43	-0.55	-0.69	-0.17	-0.39	0.20	0.08	-0.17	0.36	-0.04	-0.62	0.34	-0.45	0.16	.36	0.02	-.69
	F2	-0.22	0.00	0.21	0.26	0.30	-0.19	1.00	0.00	0.20	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.30	0.00	0.00	0.00	0.00	0.17	0.20	.30	0.17	-.22
	F3	-0.09	-0.24	0.72	0.57	0.69	-0.29	0.00	1.00	0.78	0.68	0.57	0.07	0.68	0.81	0.62	0.43	0.39	0.75	0.05	-0.24	0.45	0.39	0.61	0.42	0.29	0.68	0.51	.81	0.05	-.29
	F4	-0.20	0.12	0.59	0.52	0.64	-0.21	0.20	0.78	1.00	0.56	0.48	0.09	0.56	0.77	0.65	0.17	0.22	0.77	0.28	-0.10	0.33	0.50	0.53	0.12	0.21	0.73	0.66	.78	0.09	-.21
	F5	-0.46	-0.22	0.83	0.62	0.40	-0.34	0.00	0.68	0.56	1.00	0.29	0.53	1.00	0.88	0.71	0.58	0.88	0.87	0.09	-0.42	0.76	0.62	0.92	0.59	0.49	0.76	0.63	1.00	0.09	-.46
	F6	-0.32	-0.42	0.07	0.42	0.83	-0.20	0.00	0.57	0.48	0.29	1.00	-0.45	0.29	0.46	0.29	0.45	0.04	0.43	-0.05	-0.25	-0.07	0.04	0.18	0.24	-0.04	0.64	0.26	.83	0.04	-.45
	F7	-0.34	0.35	0.74	0.29	-0.27	-0.40	0.30	0.07	0.09	0.53	-0.45	1.00	0.53	0.26	0.42	0.23	0.67	0.34	-0.15	-0.29	0.63	0.26	0.45	0.35	0.40	0.08	0.25	.74	0.07	-.45
	F8	-0.46	-0.22	0.83	0.62	0.40	-0.34	0.00	0.68	0.56	1.00	0.29	0.53	1.00	0.88	0.71	0.58	0.88	0.87	0.09	-0.42	0.76	0.62	0.92	0.59	0.49	0.76	0.63	1.00	0.09	-.46
	C1	-0.40	-0.19	0.73	0.55	0.56	-0.43	0.00	0.81	0.77	0.88	0.46	0.26	0.88	1.00	0.87	0.66	0.54	0.92	0.08	-0.37	0.67	0.54	0.81	0.52	0.17	0.90	0.55	.92	0.08	-.43
	C2	-0.57	0.07	0.71	0.50	0.24	-0.55	0.00	0.62	0.65	0.71	0.29	0.42	0.71	0.87	1.00	0.73	0.38	0.80	-0.26	-0.60	0.64	0.38	0.62	0.45	-0.01	0.69	0.30	.87	0.07	-.60
	C3	-0.55	-0.31	0.45	0.31	0.34	-0.69	0.00	0.43	0.17	0.58	0.45	0.23	0.58	0.66	0.73	1.00	0.35	0.54	-0.42	-0.56	0.52	0.03	0.43	0.67	-0.21	0.64	0.00	.73	0.03	-.69
	C4	-0.40	-0.19	0.73	0.55	0.15	-0.17	0.00	0.39	0.22	0.88	0.04	0.67	0.88	0.54	0.38	0.35	1.00	0.61	0.08	-0.37	0.67	0.54	0.81	0.52	0.69	0.43	0.55	.88	0.04	-.40
	C5	-0.48	-0.18	0.74	0.67	0.52	-0.39	0.00	0.75	0.77	0.87	0.43	0.34	0.87	0.92	0.80	0.54	0.61	1.00	0.03	-0.42	0.62	0.61	0.75	0.31	0.39	0.83	0.57	.92	0.03	-.48
	C6	0.54	0.23	-0.07	-0.37	0.31	0.20	0.00	0.05	0.28	0.09	-0.05	-0.15	0.09	0.08	-0.26	-0.42	0.08	0.03	1.00	0.66	-0.15	0.27	0.22	-0.05	0.11	0.24	0.55	.66	0.03	-.42
	C7	0.71	0.18	-0.36	-0.59	0.13	0.08	0.26	-0.24	-0.10	-0.42	-0.25	-0.29	-0.42	-0.37	-0.60	-0.56	-0.37	-0.42	0.66	1.00	-0.45	-0.37	-0.40	-0.10	-0.28	-0.18	-0.11	.71	0.08	-.60
	C8	-0.47	-0.29	0.74	0.61	0.10	-0.17	0.30	0.45	0.33	0.76	-0.07	0.63	0.76	0.67	0.64	0.52	0.67	0.62	-0.15	-0.45	1.00	0.67	0.83	0.35	0.40	0.50	0.49	.83	0.10	-.47
	T1	-0.26	-0.19	0.44	0.55	0.15	0.36	0.00	0.39	0.50	0.62	0.04	0.26	0.62	0.54	0.38	0.03	0.54	0.61	0.27	-0.37	0.67	1.00	0.81	-0.19	0.69	0.43	0.83	.83	0.03	-.37
	T2	-0.36	-0.24	0.72	0.57	0.31	-0.04	0.00	0.61	0.53	0.92	0.18	0.45	0.92	0.81	0.62	0.43	0.81	0.75	0.22	-0.40	0.83	0.81	1.00	0.42	0.53	0.68	0.77	.92	0.18	-.40
	T3	-0.21	-0.10	0.52	0.10	0.29	-0.62	0.00	0.42	0.12	0.59	0.24	0.35	0.59	0.52	0.45	0.67	0.52	0.31	-0.05	-0.10	0.35	-0.19	0.42	1.00	-0.18	0.47	0.00	.67	0.10	-.62
	CA1.1	-0.13	-0.18	0.47	0.59	0.06	0.34	0.00	0.29	0.21	0.49	-0.04	0.40	0.49	0.17	-0.01	-0.21	0.69	0.39	0.11	-0.28	0.40	0.69	0.53	-0.18	1.00	0.05	0.63	.69	0.05	-.28
	CA1.2	-0.40	-0.27	0.51	0.45	0.77	-0.45	0.17	0.68	0.73	0.76	0.64	0.08	0.76	0.90	0.69	0.64	0.43	0.83	0.24	-0.18	0.50	0.43	0.68	0.47	0.05	1.00	0.57	.90	0.05	-.45
	CA1.3	-0.09	0.00	0.52	0.43	0.49	0.16	0.20	0.51	0.66	0.63	0.26	0.25	0.63	0.55	0.30	0.00	0.55	0.57	0.55	-0.11	0.49	0.83	0.77	0.00	0.63	0.57	1.00	.83	0.16	-.11

If there is a correlation score of 1 in a correlation matrix, this means we can predict the scores of one item by the scores of the other item with perfect accuracy. Following this premise, we found it would be interesting to discuss the correlations scores between items of different categories.

The following pairs have high positive correlation scores (marked green in Table 4.12):

1. **T2** and **F5** (score of 0.92) **– Supplier lead-time** (T2) and **Critical parts suppliers** (F5). The high positive correlation score can be explained by time. The supplier's lead-time will increase if the critical parts suppliers fail or are late upon manufacturing or delivering;

2. **T2** and **F8** (score of 0.92) **– Supplier lead-time** (T2) and **Standardized or common parts** (F8). This score can be explained by time. If the supplier fails or is late to manufacture a standardized part then the supplier's lead-time is increased;

3. **CA1.2** and **C1** (score of 0.90) **– Distancing between supports** (CA1.2) and **Warranty costs** (C1). These items are correlated because warranty costs happen after the installation is done. If distancing between supports is done incorrectly or needs to be fixed after the installation, then there will be warranty costs. An increase in CA1.2 could mean an increase in C1.

Items **Q4** and **F1** (marked orange in Table 4.12) have a low correlation score of 0.02 and the pair represents: **Suggestions made to suppliers** (Q4) and **Batch size** (F1). This score is understandable as suggestions made to suppliers and batch size may not have anything in common, unless the suggestion is about batch size, but that should be discussed directly with the supplier.

The following pairs have high negative correlation scores (marked red in Table 4.12):

1. **F1** and **C3** (score of -0.69) – **Batch size** (F1) and **Production capacity** (C3). The negative correlation score is expected; since if a batch size increases then the production capacity costs of the batch will decrease. Larger lots of parts manufactured will decrease the production cost of a single item (mass production) at the risk of losing product quality;

2. **F1** and **T3** (score of -0.62) – **Batch size** (F1) and **Delivery on time to the client** (T3). This can be explained through the flexibility of manufacturing batch sizes. By having the flexibility to change production of the size of batches, this can lead to an increase in response to demand. This could then increase the capacity of delivering orders on time to the client;

3. **Q1** and **F2** (score of -0.22) – **Rework** (Q1) and **Increased flexibility** (F2). When a company has the ability to change production, it can manufacture smaller batches which deliver a product with higher quality. In turn this will help decrease reworks. As increased flexibility increases, rework decreases.

As Table 4.12 considers all items of the study, it would also be interesting to carry out studies considering each individual category and its corresponding items. These are done from Table 4.13 - 4.17.

Since we are testing for convergent validity, it is important to understand that the desired correlation scores must be positive and of high score. High positive correlation scores prove that items assigned to a category are indeed related to it. While if correlation scores are negative, it shows that items relate in the opposite manner to their assigned category. Finally, low correlation scores (near zero value) indicate that items have almost no convergent validity.
Although convergent validity is a difficult concept to quantify, some solutions to increase convergent validity are now proposed below:

1. If items have negative correlation scores, then they are related in the opposite manner and thus their question should be rephrased in an opposite way to its original form, so that the items can yield positive correlation scores and increase convergent validity;

2. If items have low correlation scores, then the items should be replaced because they have almost no convergent validity.

We will now analyse the correlation scores for the items of each category individually. We begin with Quality's items correlations.

Table 4.13 – Quality items correlation

Inter-Item Correlation Matrix					
	Q1	**Q2**	**Q3**	**Q4**	**Q5**
Q1 - Rework	1.00	0.25	-0.29	-0.71	-0.06
Q2 - Employees suggestions	0.25	1.00	0.08	-0.45	-0.35
Q3 - Implemented suggestions	-0.29	0.08	1.00	0.58	0.28
Q4 - Suggestions made to suppliers	-0.71	-0.45	0.58	1.00	0.35
Q5 - Management sharing information with employees	-0.06	-0.35	0.28	0.35	1.00

Table 4.13 items have positive and negative correlation scores. We will now discuss the marked scores:

1. A medium score of 0.58 (marked in green in Table 4.13) is found between **Implemented suggestions** (Q3) and **Suggestions made to suppliers** (Q4). This is unexpected as implemented suggestions are aimed at Tecnodeck and suggestions to suppliers are aimed at the supplier's facility. The correlation score should be lower;
2. A high negative correlation score of -0.71 (marked in red in Table 4.13) is found between **Suggestions made to suppliers** (Q4) and **Rework** (Q1). This happens because rework is an uncommon event at Tecnodeck and is considered less important by workers, which we discovered during interviews. In normal circumstances rework is performed after receiving parts from the suppliers if these are found faulty. Ideally this pair should have a medium or high positive correlation score because workers can make suggestions to suppliers so that materials don't arrive at Tecnodeck with flaws that could be otherwise prevented;
3. The low correlation score of 0.08 (marked in orange in Table 4.13) found between **Employee suggestions** (Q2) and **Implemented suggestions** (Q3) is very unexpected because these items should have a very high positive correlation score. As implemented suggestions is a result of the suggestions workers make at Tecnodeck;
4. The negative correlation score of -0.35 (marked in red in Table 4.13) found between **Employee suggestions** (Q2) and **Management sharing information with employees** (Q5) is contrary to expectations. It is important that communication channels between management and shop floor workers are reliable and efficient. This is important in the dissemination of information, which has to be done efficiently in order to communicate the company's strategy to its workers. Therefore, sharing information with employees should increase the number of suggestions as more information is available. We conclude by saying that we expected to have a positive correlation score on this pair of items.

The Quality category has a total of five positive scores of low to medium score, and five negative scores. Regarding the solutions to increase convergent validity presented at the beginning of the sub-chapter, we now identify what actions should be taken considering the Quality category.

For this category we would like to have convergent validity and in order to achieve this, some of its items with negative correlations should be rephrased:

- The 1st item **Rework** (Q1) has three negative correlation scores out of four possible, which makes it an ideal candidate for rephrasing;
- The 2nd item **Employee suggestions** (Q2) has two negative correlation scores and one low positive correlation score, making it another candidate for rephrasing its question, which hopefully leads to better convergent validity results.

We conclude that the two items (Q1 and Q2) are not related to the Quality category and their questions should be rephrased. We can also conclude that Quality's items have no convergent validity.

Table 4.14 – Flexibility items correlations

Inter-Item Correlation Matrix								
	F1	F2	F3	F4	F5	F6	F7	F8
F1 - Batch size	1.00	-0.19	-0.29	-0.21	-0.34	-0.20	-0.40	-0.34
F2 - Increased flexibility	-0.19	1.00	0.00	0.20	0.00	0.00	0.30	0.00
F3 - Production capacity	-0.29	0.00	1.00	0.78	0.68	0.57	0.07	0.68
F4 - Container size	-0.21	0.20	0.78	1.00	0.56	0.48	0.09	0.56
F5 - Critical parts suppliers	-0.34	0.00	0.68	0.56	1.00	0.29	0.53	1.00
F6 - Supplier volume flexibility	-0.20	0.00	0.57	0.48	0.29	1.00	-0.45	0.29
F7 - Inventory rotation	-0.40	0.30	0.07	0.09	0.53	-0.45	1.00	0.53
F8 - Standardized or common parts	-0.34	0.00	0.68	0.56	1.00	0.29	0.53	1.00

In Table 4.14 there are high and low scores of correlation:

1. A perfect correlation score (1) is found between **Critical parts suppliers** (F5) and **Standardized or common parts** (F8). Every company would like to have more than one critical parts supplier and would also like to have standardized parts for easier manufacturing. If a company wishes to increase its flexibility, then they may do it by increasing the quantity of their critical parts suppliers and/or by increasing the number of standardized parts to facilitate production changes;
2. The high positive correlation score of 0.78 (marked in green) found between **Production capacity** (F3) and **Container size** (F4) can be explained by the relationship between the two items: if one has the flexibility to change production capacity, then container size can also change to better fit one's needs. This is a difficult argument as Tecnodeck's choice of container sizes is mostly based on financial aspects and their ability to change production capacity is reduced since they plan their production yearly because of the distance and transportation time constraints of its China based factory;
3. A medium negative correlation score of -0.45 (marked in red in Table 4.14) is found between **Supplier volume flexibility** (F6) and **Inventory rotation** (F7). The flexibility item concerns the supplier's ability to change volume and Inventory rotation regards Tecnodeck's ability to use older items first. This correlation score can be explained by the following: if the supplier can increase or decrease production according to demand, then Tecnodeck will have a lower inventory rotation activity in its warehouse;

4. A correlation score of zero (marked in orange in Table 4.14) is found between **Increased flexibility** (F2) and **Production capacity** (F3). Tecnodeck has a reduced ability to change production when considering the time and distance constraints of its China-based supplier. When comparing flexibility to production capacity it should have a low correlation score because Tecnodeck forecasts production (months ahead) according to seasonal demand.

In a total of twenty eight scores, there are sixteen positive scores, four scores of zero and eight negative scores. The positive scores range from low to high. This demonstrates that users find that the majority of items relate to the Flexibility category:

- The 1st item **Batch size** (F1) should be rephrased because it only has negative correlation scores;
- The 2nd item **Increased flexibility** (F2) only has zero and low correlation scores, as such it should be replaced.

As such we conclude that although the two items are not related to the Flexibility category, the majority of items are related and Flexibility's items have convergent validity.

Table 4.15 – Cost items correlations

Inter-Item Correlation Matrix								
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
C1 - Warranty costs (after installation)	1.00	0.87	0.66	0.54	0.92	0.08	-0.37	0.67
C2 - Batch size	0.87	1.00	0.73	0.38	0.80	-0.26	-0.60	0.64
C3 - Production capacity	0.66	0.73	1.00	0.35	0.54	-0.42	-0.56	0.52
C4 - Container size	0.54	0.38	0.35	1.00	0.61	0.08	-0.37	0.67
C5 - Reduction of manufacturing cost per unit	0.92	0.80	0.54	0.61	1.00	0.03	-0.42	0.62
C6 - WIP relative to sales	0.08	-0.26	-0.42	0.08	0.03	1.00	0.66	-0.15
C7 - Reduction of repair cost (before sale)	-0.37	-0.60	-0.56	-0.37	-0.42	0.66	1.00	-0.45
C8 - Standardized or common parts	0.67	0.64	0.52	0.67	0.62	-0.15	-0.45	1.00

Table 4.15 contains high positive and negative correlation scores:

1. The high positive correlation score of 0.92 (marked in green) found between **Warranty costs (after installation)** (C1) and **Reduction of manufacturing cost per unit** (C5) is difficult to understand, but may be explained in an item's total cost perception. If one decreases unitary manufacturing costs, then the product's quality may decrease and thus increase warranty costs;
2. A high positive correlation score of 0.87 (marked in green) is found between **Warranty costs (after installation)** (C1) and **Batch size** (C2). This can be explained with bad batches, if one has a large batch, these usually end up having problems with faulty parts or other problems. As a result, in large batches warranty costs could increase;
3. The medium negative correlation score of -0.60 (marked in red) found between **Batch size** (C2) and **Reduction of repair cost** (C7) is easily explained. When manufacturing larger batches, it is more common to have flawed materials and as such it is more difficult to

decrease repair costs. If one decreases the size of batches that results in better quality of products and thus should increase the reduction repair cost;

In a total of twenty eight scores, there are nineteen positive scores and nine negative scores. The positive scores range from medium to high, which demonstrates that users find that the majority of items relate to the Cost category:

- The 6th item **WIP relative to sales** (C6) should be replaced because it has three scores near zero out of seven possible;
- The 7th item **Reduction of repair cost (before sale)** (F7) should be rephrased because it has six negative scores out of seven possible.

We conclude that although two items are not related to the Cost category, the rest are related and so Cost's items can be said to have convergent validity.

Table 4.16 – Time items correlations

Inter-Item Correlation Matrix			
	T1	**T2**	**T3**
T1 - Client lead-time	1.00	0.81	-0.19
T2 - Supplier lead-time	0.81	1.00	0.42
T3 - Delivery on time to client	-0.19	0.42	1.00

Table 4.16 has two positive and one negative correlation score:

1. The positive correlation score of 0.81 (marked green) found between **Supplier lead-time** (T2) and **Client lead-time** (T1) can be explained in the order's time perspective. If a supplier is late with his delivery, than your clients will suffer because you can't complete their order in the expected time frame. But client lead-time shouldn't be directly related to supplier lead-time. If a supplier delivers on time and the company fails to send the order on time to the client, than the supplier isn't responsible;
2. A low negative correlation score of -0.19 (marked in red) is found between **Client lead-time** (T1) and **Delivery on time to the client** (T3). This is expected although the negative correlation score should be higher. Since delivery time is part of the client's lead-time, if the order isn't delivered on time to the client (decrease of delivery on time) then the client's lead-time increases.

The table contains positive correlation scores of medium to high value. This demonstrates that users find that 2/3 of items relate to the Time category. The 3rd item Delivery on time has one negative correlation score of low value and one positive correlation score of medium value and because of this the 3rd item could be rephrased in order to get better results. Nonetheless we conclude that although there is a low negative correlation score, the items are related to the Time category and have convergent validity.

Table 4.17 – Critical activities items correlations

Inter-Item Correlation Matrix			
	CA1.1	**CA1.2**	**CA1.3**
CA1.1 - External supports fixation	1.00	0.05	0.63
CA1.2 - Distancing between supports	0.05	1.00	0.57
CA1.3 - Distance between boards	0.63	0.57	1.00

Table 4.17 only contains positive scores:

- The medium positive correlation score of 0.63 found between **Exterior supports fixation** (CA1.1) and **Distance between boards** (CA1.3) can be explained because the two critical activities are usually performed in the same client's order;
- The low positive correlation score of 0.05 found between **External supports fixation** (CA1.1) and **Distancing between supports** (CA1.2) can be because the two critical activities aren't generally performed in the same client's order.

All of Critical Activities' scores are positive and range from low to medium value, and so we can assume that all items relate to the Critical Activities category. This was expected since the critical activities were identified by Tecnodeck's staff.

This was the final statistical treatment to be performed, which allowed for the analysis of each item's correlation in their respective categories and determined if they had convergent validity. Not all items are related to their respective category but this is expected since it was the author's own judgment that chose each set of performance measures for the five categories. The fifth category (Critical Activities) obtained the desired result, which was expected. Some of the unexpected scores have been given possible explanations. We now recap the pairs of positive and negative correlation scores in Table 4.18 below:

Table 4.18 – Summary of correlations of items per category

	Quality		Flexibility			Cost			Time		Critical Activities	
Type of correlation	Positive	High negative	High positive	High positive	Medium negative	High positive	High positive	Medium negative	High positive	Low negative	Medium Positive	Low positive
Correlation score	0.58	-0.71	0.78	1	-0.45	0.87	0.92	-0.60	0.81	-0.19	0.63	0.05
Correlation pair	Q3 and Q4	Q1 and Q4	F3 and F4	F5 and F8	F6 and F7	C1 and C2	C1 and C5	C2 and C7	T1 and T2	T1 and T3	CA1.1 and CA1.3	CA1.1 and CA1.2

In order to aid Table 4.18's analysis, we present the coded items below:

- Rework (Q1) ;
- Implemented suggestions (Q3) ;
- Suggestions made to suppliers (Q4);
- Production capacity (F3);

- Container size (F4);
- Critical parts suppliers (F5);
- Supplier volume flexibility (F6);
- Inventory rotation (F7);
- Standardized or common parts (F8);
- Warranty costs (after installation) (C1);
- Batch size (C2);
- Reduction of manufacturing cost per unit (C5);
- Reduction of repair cost (C7);
- Client lead-time (T1);
- Supplier lead-time (T2);
- Delivery on time to the client (T3);
- Exterior supports fixation (CA1.1);
- Distancing between supports (CA1.2);
- Distance between boards (CA1.3).

After discussing the correlation scores of each category we now present a summary of each category's convergent validity in Table 4.19.

Table 4.19 – Convergent validity of the five categories

	Quality		Flexibility			Cost		Time		Critical Activities	
Type of correlation	Positive	Negative	Positive	Zero	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Value of correlation (range)	Low to medium	Low to medium	Low to high	-	Low to medium	Medium to high	Medium	Medium to high	Low	Medium	-
Number of types of correlation	5	5	16	4	8	19	9	2	1	3	0
Convergent validity	**No**		**Yes**			**Yes**		**Yes**		**Yes**	

It is important that items have high positive correlation scores in order to have convergent validity, as low correlation scores indicate the absence of convergent validity. And high negative correlation scores indicate that items are related but in the opposite manner to the category.

By observing Table 4.19 we can comment upon the category's items convergent validity. The Flexibility, Cost, Time and Critical Activities items have demonstrated that they have convergent validity. Most of their correlation scores are positive and of medium to high value.

We will now discuss the convergent validity of each category's items, specially the category's items that don't have convergent validity (Quality). And what they can do to achieve it:

1. Quality's items have no convergent validity. For this category we should rephrase its 1st item - **Rework** (Q1) and 2nd item - **Employee suggestions** (Q2) in a contrary way to the original form in order to obtain positive correlation scores and thus increase convergent validity. This is due to these items having obtained mostly negative correlation scores;

2. Flexibility's items have convergent validity. Its 1st item - **Batch size** (F1) should be rephrased to increase convergent validity, Flexibility's 2nd item - **Increased Flexibility** (F2) should be replaced by another lean performance measure;
3. Cost's items have convergent validity. Cost's 7th item - **Reduction of repair cost (before installation)** (C7) could be rephrased and Cost's 6th item - **WIP relative to sales** (C6) could be replaced by another lean performance measure. These actions can be taken but are not urgent because the items have convergent validity;
4. Time's items have convergent validity. Time's 3rd item - **Delivery on time** (T3) could be rephrased, which could increase the item's correlation and thus convergent validity. This is not an urgent matter, but only a suggestion;
5. Critical Activities' items have convergent validity and so, no replacement or rephrasing of items is suggested.

Coincidently, when comparing results obtained from the reliability test and the convergent validity test, some results overlap. This greatly aids our decision of rephrasing or replacing lean performance measures.

Chief among the troublemakers are the following items: Q1-**Rework**, F1-**Batch size**, C7-**Reduction of repair cost (before sale)**. These are the worst items from Table 4.11 – Alpha if Item Deleted where they represent the biggest increase in the Cronbach-alpha coefficient value, if the item is deleted. While in the correlation matrixes of the category's items (Tables 4.13 – 4.17), they represent items that have several negative correlation scores. The three items should be rephrased in an opposite manner so we can obtain better convergent validity results.

According to both tests, the best items are: F5-**Crtical parts suppliers**, F8-**Standardized or common parts**, C1-**Warranty costs** and C5-**Reduction of manufacturing cost per unit**. These are among the best items in Table 4.11 – Alpha if Item Deleted where they represent some of the biggest decreases of the Cronbach-alpha coefficient. While in the correlation matrixes of each category's items (Tables 4.13 – 4.17), they contain several high positive correlation scores, which means they are indeed related to their assigned category.

4.5. Interview Results

This sub-chapter presents the results of the interviews performed at Tecnodeck, whilst the framework of the interviews can be found in the annex, designated Annex I. The interview's purpose, as mentioned before, is to discover management's knowledge and expectations of Lean. We performed a semi-structured interview with the manager of the Tecnodeck company, which allowed us to understand his taking and perspective on the Lean philosophy:

1. Regarding the first question, the results tell us that management has very little knowledge of the Lean philosophy. Interviewees only have knowledge of Lean acquired in the past;

2. The second question's answers are similar to the first question's, with interviewees only having past knowledge of Lean. The interviewees also added that they knew Lean had been applied in the automotive industry;
3. The third question's results are mostly consensual. The interviewees have no expectation of Lean, as they know little of it. This is an expectable answer according to the previous answers;
4. In the fourth question, the information obtained was that they didn't know at this time if Lean had been applied in the WPC industry;
5. Fifth and final question, where management told us that there were some areas of Tecnodeck that could be improved. These are: stock management and handling of inventory. This is great information as these two areas have been targeted by Lean in other industries with considerable success.

Since the interviewee had a scarce and past knowledge of Lean, the results of the interview are not unexpected. Good information has been collected through the interview (see Annex II), such as possible areas of improvement in the company. The interview proved to be a valid resource when developing a case study and contributed to the identification of improvement opportunities.

4.6. Improvement opportunities

In this sub-chapter improvement opportunities will be suggested to Tecnodeck by the result of the analysis of the input obtained from interviews with Tecnodeck's manager's regarding areas of possible improvement in the company and the survey's results. The two sources of information will contribute to the reasoning for the suggested improvement opportunities.

It is useful to start by considering the worst performance measures in both statistical tests: rework (Q1), batch size (F1) and reduction of repair cost (C7). These performance measures belong to three different categories: quality, flexibility and cost, where we can start to suggest improvement opportunities:

- Testing statistical software to ensure the product's quality and reduce number of scraps (Quality - Q1);
- Applying 5S's technique to improve quality of the product and improve processes (Quality);
- Identifying root causes of scraps in order to eliminate origin of scraps and not the consequence (Quality – Q1 and Cost);
- Manufacturing smaller batches can lead to a decrease of reworks and increase of product's quality (Quality – Q1 and Cost – C7);
- Ability to change capacity according to demand in order to increase batch size flexibility (Flexibility – F1 and Cost);

- Reduction of repair cost through production of better quality materials (Quality – Q1 and Cost – C7).

In order to correct rework, batch size and reduction of repair cost items, we considered improvement opportunities in the Quality and Flexibility categories which had financial implications, thereby relating these to the Cost category.

Secondly, we take into consideration Tecnodeck's management identification of possible improvement opportunities in inventory handling and stock management areas. These two areas can have improvement opportunities belonging to the quality, cost, flexibility and time categories:

- Reviewing trends in a shorter time frame as part of new inventory management strategies (Flexibility);
- Detailing inventory planning as demands can change quickly (Flexibility);
- New handling techniques or automation in order to improve handling (Flexibility);
- Creating multi-skilled teams so that employees can do various tasks in order to cover eventual gaps in demand and as part of collaborator training (Flexibility);
- Creating safety stock levels according to demand in order to prevent inventory stock-out and therefore delaying orders unnecessarily (Flexibility and Cost);
- Creating routes for transportation of inventory in the warehouse in order to improve handling errors and decrease lead times (Flexibility and Time);
- Consider choosing a new picking technology, such as radio frequency in order to decrease time spent on inventory needlessly and which allows better tracking of inventory and eliminates extra physical data (Time);
- Creating a sub-assembly of the product before sending orders in order to improve handling and space utilization (Flexibility);
- Protection of value-adding techniques in order to avoid rivals from copying since we discovered that rivals could be trying to imitate Tecnodeck's value-adding techniques (Critical Activities).

Finally, it was the author's judgment that if there was the opportunity to install a new manufacturing line in Portugal, than some great improvements can derive from this supposition:

- Greater flexibility in manufacturing (Flexibility);
- Adoption of information system that develops greater integration with suppliers (Flexibility);
- Adoption of JIT technique to decrease lead times, setup times, transportation costs, manufacturing costs, inventory costs (Flexibility, Cost and Time).

We have suggested a list of possible improvement opportunities for the five categories based on the surveys' results, interviews with management and the author's judgment. We now present a summary of the identified improvement opportunities in Table 4.20.

Table 4.20 – Improvement opportunities

Improvement Opportunities	
Quality	• Rework* - identification of faults that lead to rework • Application of statistical software to control the product's quality and decrease scraps (Six Sigma); • Application of 5 S's technique to improve product's quality; • Identify root causes of scraps to eliminate the origin and not the consequence; • Application of statistical software if new manufacturing line is installed; • Smaller production batches (with new manufacturing line) – increases the product's quality.

Flexibility	• Inventory management strategies – review trends monthly, detail inventory planning as demand changes constantly;
	• Improve handling – new techniques, technology or automation can help decrease errors in handling;
	• Train employees to perform several tasks – create multi-skilled teams;
	• Change capacity by allocating resources according to demand (daily demand is preferred);
	• Creation of safety stock level according to seasonal demand – to prevent shortage of inventory and thus delaying orders;
	• Creation of routes for inventory transportation in the warehouse – improves handling errors also;
	• Create sub-assemblies of the products before dispatching orders, to optimize material handling and space usage;
	• New manufacturing line:
	  ○ New manufacturing line will allow greater production flexibility (JIT production);
	  ○ Greater integration with suppliers – develop a better information system;
	  ○ Greater flexibility with decrease of setup times because of JIT.

Cost	• Reduction of repair cost (before sale)* - production of better quality materials;
	• Creation of safety stock level according to seasonal demand – to prevent shortage of inventory and incur cost;
	• **New manufacturing line (JIT production):**
	  ○ Decrease of transportation costs;
	  ○ Decrease of manufacturing cost and associated costs like repair before sale;
	  ○ Decrease of inventory costs – maintenance and space usage.

Time	• Creation of routes for inventory transportation in the plant/company warehouse;
	• Consider choosing a new picking technology – RF (radio frequency),;
	• **New manufacturing line:**
	  ○ Implementation of JIT technique – decreases lead times;
	  ○ Great decrease of transportation shipping time with new manufacturing line in Portugal;
	  ○ Decrease of client and supplier lead times with new manufacturing line.

Critical Activities	• Protect techniques to avoid rivals from copying; • Development of new value adding processes.

We have tried to discover as many opportunities as possible, shown in Table 4.20, especially for the **Time** and **Flexibility** category since these were the two most important categories considering the users' results. According to sub-chapter 4.4.1 (Survey Results Commentaries) item **Rework** (Q1) and item **Reduction of repair cost** (C7), which are marked with an asterisk (*) produced unexpected scores and thus presented themselves as features where Tecnodeck could improve its processes even though they are uncommon events. Finally, according to sub-chapter 4.4.2 (Survey Results Statistical Treatment) we considered three lean performance measures, **Rework** (Q1), **Batch size** (F1) and **Reduction of repair cost before sale** (C7), which were found to have a negative impact on the reliability and convergent validity test. Although **Rework** (Q1) and **Reduction of repair costs** (C7) have already been mentioned regarding sub-chapter 4.4.1, we tried to find improvement opportunities.

4.7. Strategy formulation

As stated in the literature review, we have chosen Porter's generic strategies (Differentiation, Cost Leadership and Focus) when considering the development of strategies for the countries that Tecnodeck has the greatest interest in. Other generic strategies could be employed such as Treacy and Wiersema's strategies that are focused more on the customer, by having a customer relationship factor. But since we have more data regarding the WPC industry's market, we judged it would be better to have a market-oriented strategy; thus Porter's strategies have been chosen.

As such, based upon Porter's generic strategies, the results from the survey and interviews with Tecnodeck's management, we have developed the following strategies for Tecnodeck for three countries: Portugal, Italy and Belgium.

Considering the existing market difficulties and slow growth of the Portuguese market, it is best if Tecnodeck can maintain its position as market leader and thus Tecnodeck should strive to consolidate its position through the differentiation of its products which is in accordance with its existing strategy that resembles a differentiation strategy (stated before). According to Porter's generic strategies, the advised strategy in this situation should be the cost leadership strategy, but this could possibly change Tecnodeck's client's perception of the product. Changing the product from a high-end item to a cheaper and more affordable product could have a negative impact on the existing client's perception that may not be in Tecnodeck's best interests.

A mix of the two strategies has been discouraged by Porter, unless business units are clearly separated and so the final strategy should be to continue with the **differentiation** strategy that Tecnodeck has been employing in Portugal. The purpose of suggesting a differentiation strategy is so Tecnodeck can convince potential clients that there is a gap between their product/service and its rivals', by presenting a unique set of product characteristics such as:

shape, color, design and technology applied or the quality of the service provided. The gap we intend to create can help Tecnodeck maintain its leader position in the market.

On the international level, as the economic situation in Belgium is greatly different from the Portuguese, and considering their maturity towards this type of product, it is proposed that Tecnodeck invest further in this country, by trying to establish a market position in it. This can be done with the help of local people that have knowledge of customers' needs and bureaucratic know-how. Tecnodeck should target its customers, conducting a focused market segment strategy, by targeting locations such as: restaurants and cafés (places with an outside area). Since Tecnodeck prizes its independence, a joint-venture with another company would be difficult. By analyzing Porter's generic strategies, we consider the focus differentiation strategy which is best suited for new ventures as is the Belgian opportunity, where it could help Tecnodeck by growing quickly in a specific market, such as the restaurant business. With the focus strategy a company has greater predictability of the outcome and the needs of the targeted customers, by more easily identifying what features customer's value in the specific segment the company is targeting. Thus a **focus differentiation** strategy should be employed in order to begin establishing a position in the Belgian market and then gaining market share, in the future Tecnodeck could possibly change strategies if they prove more profitable than the focus strategy.

Finally, in Italy, Tecnodeck is already being represented by the major distributor *Sogimi* and as it is happening in Portugal, Italy is also going through an economic convulsion. It is better if Tecnodeck can gain market share through the *Sogimi* group, while possibly diminishing their biggest rival's market share, Greenwood. Italy can thus have two possible Porter generic strategies: cost leadership or differentiation, focus has not been considered since Tecnodeck has an established position in the Italian market. The disadvantages of the cost leadership strategy have been explained for the Portuguese market and could also be applied to the Italian market, so it wouldn't be wise to pursue the cost leadership strategy. As Italy is an emerging market of composite deck, it is very important for Tecnodeck to succeed and so the differentiation strategy is going to be considered. Tecnodeck wishes to maintain and/or increase its market share in the Italian market and this can be done by developing new product applications where it may be able to recover clients from its biggest rival. By offering a wider range of products with a perceived higher product value than its rival, Tecnodeck could create the "gap" between the two companies that is one of main purposes of the differentiation strategy. Thus, the suggested strategy for Italy is the **differentiation** strategy.
Although Portugal and Italy have the same strategy and a similar economic situation, they have quite different market situations. In Portugal, Tecnodeck is the market leader while in Italy it has big rival in Greenwood with which to compete. The same strategy is suggested but with different market settings.

As stated before, the strategy for Portugal presented in sub-chapter 4.2.5. – Balanced Scorecard is solely based on interviews with management and thus has a different basis from the strategy presented in this chapter.

We have presented three strategies for three different countries, each with its own unique market situation.

5. CONCLUSIONS

5.1. Conclusions

Upon discovering a reduced number of data regarding lean application in the WPC industry and together with Tecnodeck's knowledge of the industry, we were able to detect an opportunity to increase the available data regarding lean's application.

Throughout the case study and together with the results from the survey we can begin to answer the question posed at the beginning of the study: "How does the wood-plastic composite industry value the identified lean performance measures?" We consider that an analysis of the WPC industry's leading company in the market (Tecnodeck) should accurately reflect what the industry values. Thus, the importance that Tecnodeck's staff gives to each performance measure can represent the input of the WPC industry's collaborators. According to the results, the most important categories are: **Time** and **Flexibility**. Whereas the most important performance measures according to the statistical tests are: **Critical parts suppliers** (F5), **Standardized or common parts** (F8), **Warranty costs (after installation)** (C1) and **Reduction of manufacturing cost per unit** (C5). These are the categories and performance measures that the industry values the most when regarding the list of performance measures we have presented.

There are some results which are unexpected, such as: the small importance of quality's **Rework** (Q1) has to employees, the high importance of flexibility of **Container size** (F4) and the small importance of Cost's **WIP value relative to sales** (C6). Rephrasing and replacing lean performances measures have been suggested because of their bad scores on the reliability and convergent validity test simultaneously. These include rephrasing: **Rework** (Q1), **Batch size** (F1) and **Reduction of repair cost** (C7), and replacing **WIP relative to sales** (C6).

5.1. Limitations of the study

The study had limitations regarding the reduced number of participants but the majority of the case study company's staff answered the questionnaire.

5.2. Contribution to the theory

The study's theoretical part contributes with a review of lean performance measures of several authors and the creation of a list with the performance measures in order to evaluate their importance. The list can be used in different industries and/or companies and constitutes the groundwork for the study of lean applied to a relatively new industry.

5.3. Contribution to the practical part

The study's practical part contributes with the importance attributed to each performance measure according to case study company's staff and the identification of the improvement opportunities based on the statistical results and interviews with management that yielded areas which were targeted for improvement.

We suggest the development of a Lean strategy for Tecnodeck according to the results of the interviews, in which management identified possible improvements that could be made in stock management and inventory handling areas. If a manufacturing line is installed in Portugal then it is crucial that a lean strategy is developed and implemented in order to improve these areas. Possible improvements have also been suggested (see Table 4.20) and with the help of a person with extensive knowledge of Lean, these could be implemented. The possibility of applying Lean distribution when a manufacturing line is installed in Portugal is an option worthy of consideration.

5.4. Options for further investigation

Further study of the Lean philosophy can be realized in the Wood Composite Industry, as initial performance measures have been identified and there is still a lot of research and work regarding Lean's implementation in this industry. The development of a lean procedure for the WPC industry based on its principles and continuous improvement techniques would be a good subject to continue this study.

Secondly we suggest as a further study, to perform a discriminant validity test with the identified performance measures, in order to complete the study of the construct's validity, since only convergent validity was accomplished.

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ANNEX

Annex I - Interview Framework

"Venho por este meio colocar-lhe algumas perguntas que contribuíram para a minha tese, as perguntas incidiram na filosofia Lean, que tem sido largamente aplicada em várias indústrias com sucesso durante vários anos e consiste em eliminar desperdícios e criar valor para o cliente através de melhores produtos e/ou serviços. As perguntas são as seguintes:"

1. Qual o seu conhecimento actual sobre a filosofia Lean?
2. Qual o seu entendimento sobre o Lean?
3. Quais as suas expectativas que o Lean possa trazer à empresa?
4. Em que medida a aplicação da filosofia Lean poderá melhorar o desempenho da empresa?
5. Quais os processos que entende que sejam críticos à Tecnodeck tendo em conta a filosofia Lean?

Annex II - Interview Results

Manager

1. Sim sabe mas tem conhecimento só antigo.
2. Sabe que foi uma filosofia usada na indústria automóvel.
3. Não sabe, não tem expectativas.
4. Não sabe se já foi aplicada na indústria WPC ainda. Pode haver melhorias mas não sabe.
5. Gestão de stocks e manuseamento de stocks são actividades critica onde pode haver melhorias.

Annex III – Survey form

Questionário Tese

O questionário tem como base avaliar a importância de indicadores Lean, que são indicadores de uma filosofia "magra" baseada na eliminação de desperdícios que não adicionem valor ao produto final que é entregue ao cliente. Peço que avaliem de 1 a 5, sendo 1 muito pouco importante e 5 muito importante, os seguintes indicadores:

Utilizador

Informação relativa à idade, sexo e ocupação

Idade *

Sexo *

- Masculino
- Feminino

Ocupação (Cargo que desempenha na empresa)

Qualidade

Indicadores que estão relacionados com a categoria de qualidade, referente ao produto e/ou serviço

1) Reparações (rework) *Operações que envolvam reparações do produto antes da venda (produto recebido no armazém com defeito)

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

2) Sugestões de trabalhadores *

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

3) Sugestões implementadas *Sugestões propostas por trabalhadores são implementadas

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

4) Sugestões a fornecedores *Sugestões feitas aos fornecedores

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

5) Partilha de informação da gestão com funcionários *

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

Flexibilidade

Indicadores relativos à flexibilidade da recepção, produção/manufactura e entrega do produto

1) Tamanho de lotes de produção *Importância da facilidade em alterar volume dos lotes de produção (Tecnodeck)

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

2) Aumento da flexibilidade da empresa *Aumento da flexibilidade na produção da empresa

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

3) Capacidade de produção *Importância em alterar a capacidade de produção

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

4) Tamanho de contentores *

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

5) Fornecedores de peças críticas *Importância de ter mais de um fornecedor para peças críticas

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

6) Flexiblidade de volume do fornecedor *Flexibilidade que o fornecedor tem em alterar o volume de produção

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

7) Rotação de stock *Importância da utilização de stock excedente

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

8) Peças comuns ou estandardizadas *Importância de ter peças comuns ou estandardizadas entre aplicações diferentes do produto

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

Custos

Indicadores relativos aos custos associados ao produto e/ou serviço

1) Custos de garantia do produto pós-instalação *Importância do produto não necessitar de reparação pós-instalação

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

2) Tamanho do lote de produção *Influência do tamanho do lote de produção nos custos (Tecnodeck)

1 2 3 4 5

Muito pouco importante	○	○	○	○	○	Muito importante

3) Capacidade de produção *Importância da alteração do volume de produção nos custos

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

4) Tamanho do contentor *Influência do tamanho do contentor nos custos

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

5) Redução de custo unitário de produção/manufactura *

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

6) Valor de WIP relativo a vendas *Valor de Work-in-process (peças em construção) relativo ao volume de vendas

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

7) Redução de custos de reparação do produto antes da venda *Produto recebido no armazém com defeito

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

8) Peças comuns ou estandardizadas *Importância que a existência de peças comuns ou estandardizadas têm na redução dos custos

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

Tempo

Indicadores relativos à categoria de tempo de recepção do fornecedor, produção/manufactura e entrega ao cliente do produto

1) Lead-time do cliente *Tempo desde o pedido de encomenda até esta ser expedida ao cliente

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

2) Lead-time do fornecedor *Tempo desde o pedido de encomenda até esta ser expedida à Tecnodeck

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

3) Entrega a tempo ao cliente *ou Entrega dentro do prazo ao cliente?

	1	2	3	4	5	
Muito pouco importante	○	○	○	○	○	Muito importante

4) Tempo de fluxo da encomenda *Tempo que a encomenda passa na empresa desde recepção do material na Tecnodeck até expedição, num período com maior procura

- ◉ 0 - 25%
- ○ 26 - 50%
- ○ 51 - 75%
- ○ 76 - 100%

5) Tempo de fluxo da encomenda *Tempo que a encomenda passa na empresa desde recepção do material na Tecnodeck até expedição, num período com menor procura

- ◉ 0 - 25%
- ○ 26 - 50%
- ○ 51 - 75%
- ○ 76 - 100%

6) Percentagem de tempo de criação de valor *Percentagem de tempo em que é adicionado valor ao produto desde o inicio da montagem, num período com maior procura

- ◉ 0 - 25%
- ○ 26 - 50%
- ○ 51 - 75%
- ○ 76 - 100%

7) Percentagem de tempo de criação de valor *Percentagem de tempo em que é adicionado valor ao produto desde o inicio da montagem, num período com menor procura

- ◉ 0 - 25%
- ○ 26 - 50%
- ○ 51 - 75%
- ○ 76 - 100%

Actividades Críticas

Actividades do processo de montagem do Tecnodeck, que acrescentam valor ao produto e que não são realizadas pela concorrência. (Comparar qual a actividade mais importante)

1.1) Actividade critica - Fixação suportes exteriores *Importância que esta actividade crítica tem no processo de montagem do Tecnodeck

	1	2	3	4	5	
Muito pouco importante	◯	◯	◯	◯	◯	Muito importante

1.2) Actividade critica - Distanciamento entre suportes *Importância que esta actividade crítica tem no processo de montagem do Tecnodeck

	1	2	3	4	5	
Muito pouco importante	◯	◯	◯	◯	◯	Muito importante

1.3) Actividade crítica - Distância entre réguas *Importância que esta actividade crítica tem no processo de montagem do Tecnodeck

	1	2	3	4	5	
Muito pouco importante	◯	◯	◯	◯	◯	Muito importante

Sugestões

Sugestões dos utilizadores

Sugestões que os utilizadores tenham a nível do questionário

Submit